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Chu et al.

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(54) **NON-GLARE REFLECTIVE LED LIGHTING APPARATUS WITH HEAT SINK MOUNTING**

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Related U.S. Application Data

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(60) Provisional application No. 61/055,858, filed on May 23, 2008, provisional application No. 61/057,289, filed on May 30, 2008, provisional application No. 61/118,202, filed on Nov. 26, 2008.

(51) **Int. Cl.**
F21V 7/00 (2006.01)
F21V 23/00 (2015.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F21V 7/0008*** (2013.01); ***F21K 9/137*** (2013.01); ***F21V 19/0015*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC ... F21V 29/04; F21V 2101/02; F21V 29/006; F21V 59/51; F21V 29/56; F21K 9/00; F21S 48/335; F21W 2131/301
USPC 362/373, 294, 547
See application file for complete search history.

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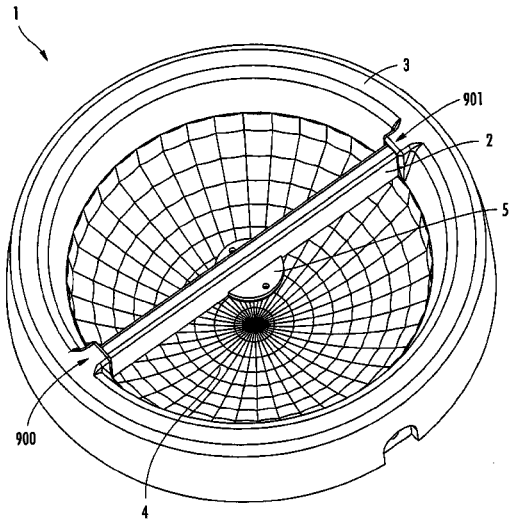
(57) **ABSTRACT**

A lighting apparatus contains a main housing; a reflector disposed within the main housing, and having a front side and a rear side; a heat conducting body comprising at least two heat pipes, wherein a first portion of the at least two heat pipes are parallel to a central axis of the lighting apparatus on the front side of the reflector, and a second portion of each of the at least two heat pipes is in the rear side of the reflector and is thermally coupled to the main housing; a heat conducting head located on the front side of the reflector, and is thermally coupled to the heat conducting body; at least two light-emitting diodes ("LEDs") thermally coupled to the heat conducting body, and being positioned to face the front side of the reflector so that light emitted from the LEDs are directed to said front side.

20 Claims, 25 Drawing Sheets



(51) **Int. Cl.**

F21V 29/00	(2015.01)
F21K 99/00	(2010.01)
F21V 19/00	(2006.01)
F21V 29/507	(2015.01)
F21V 29/77	(2015.01)
F21V 29/85	(2015.01)
F21V 7/04	(2006.01)
F21V 7/06	(2006.01)
F21V 7/07	(2006.01)
F21V 7/08	(2006.01)
F21Y 101/02	(2006.01)
F21V 29/89	(2015.01)

(52) **U.S. Cl.**

CPC ***F21V 23/005*** (2013.01); ***F21V 29/004*** (2013.01); ***F21V 29/006*** (2013.01); ***F21V 29/507*** (2015.01); ***F21V 29/773*** (2015.01); ***F21V 29/85*** (2015.01); *F21V 7/048* (2013.01); *F21V 7/06* (2013.01); *F21V 7/07* (2013.01); *F21V 7/08* (2013.01); *F21V 29/89* (2015.01); *F21Y 2101/02* (2013.01)

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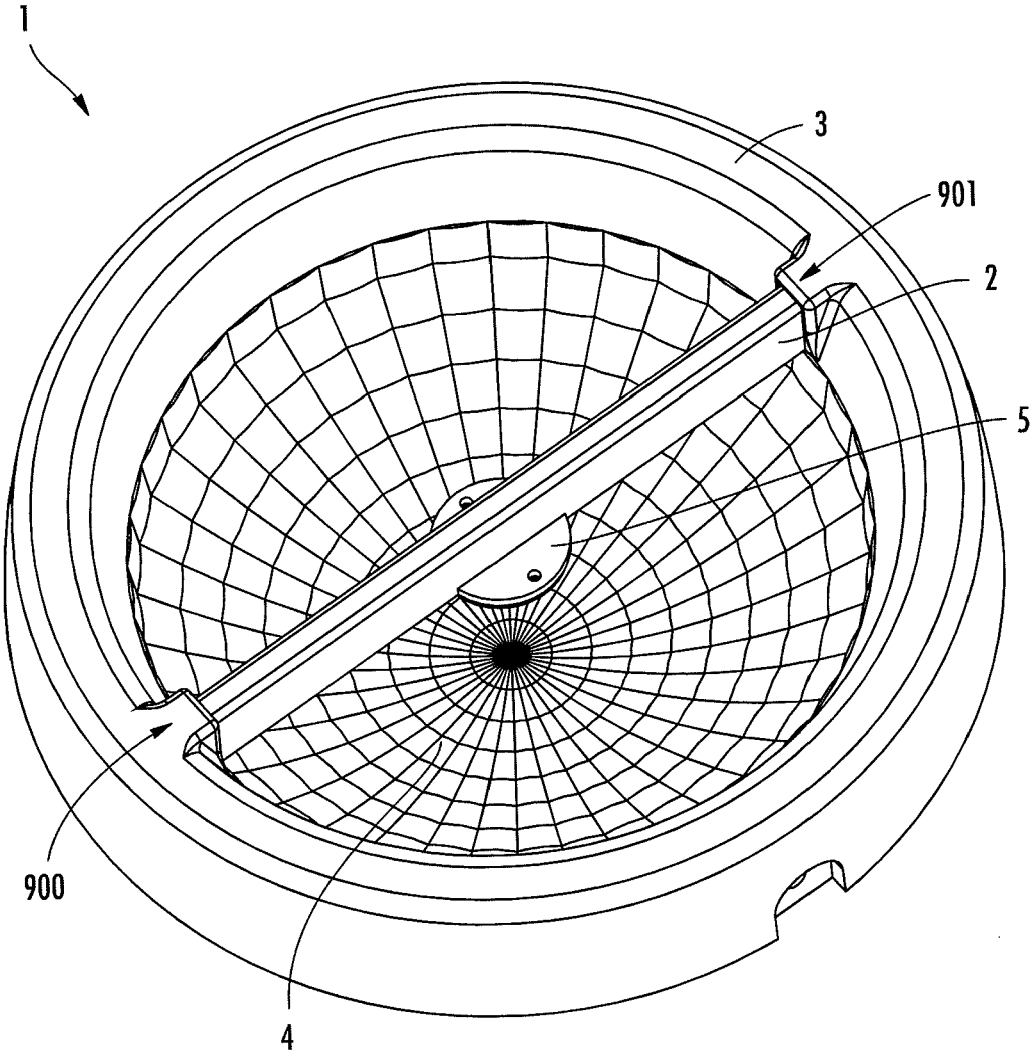


FIG. 1

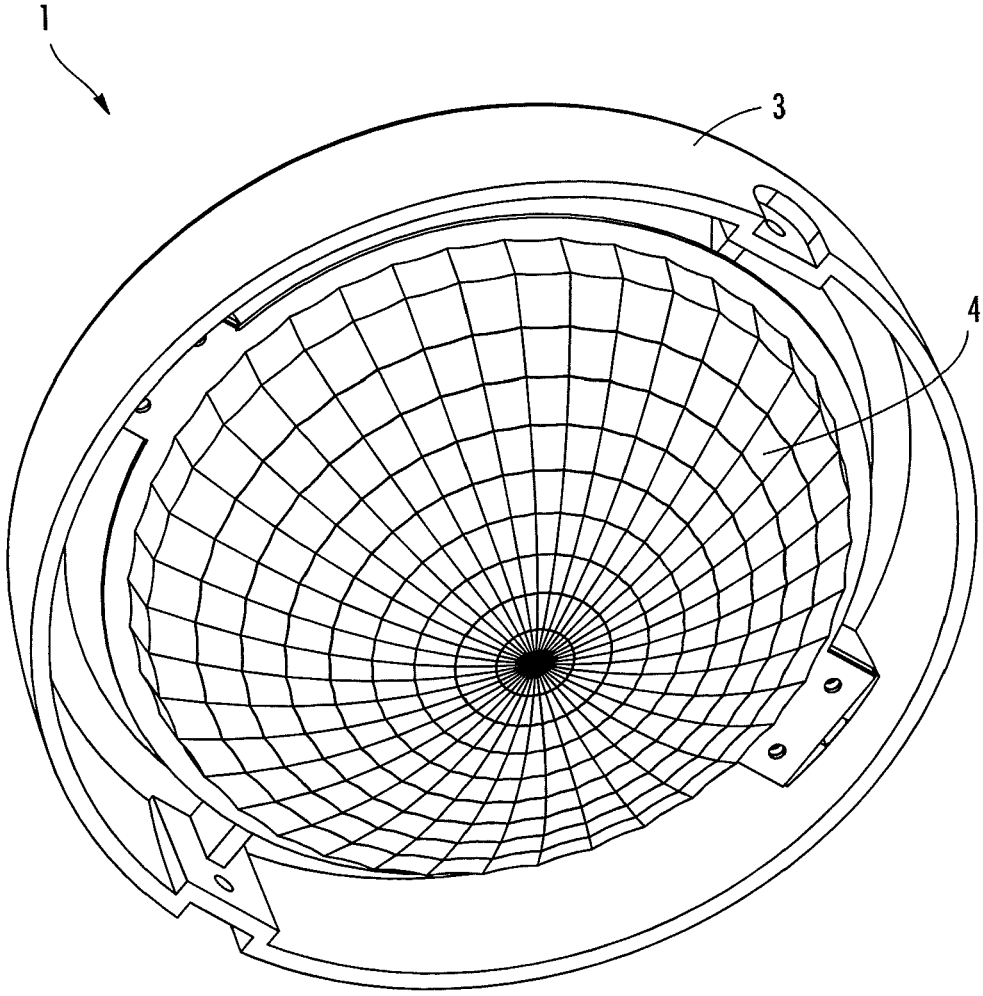


FIG. 2

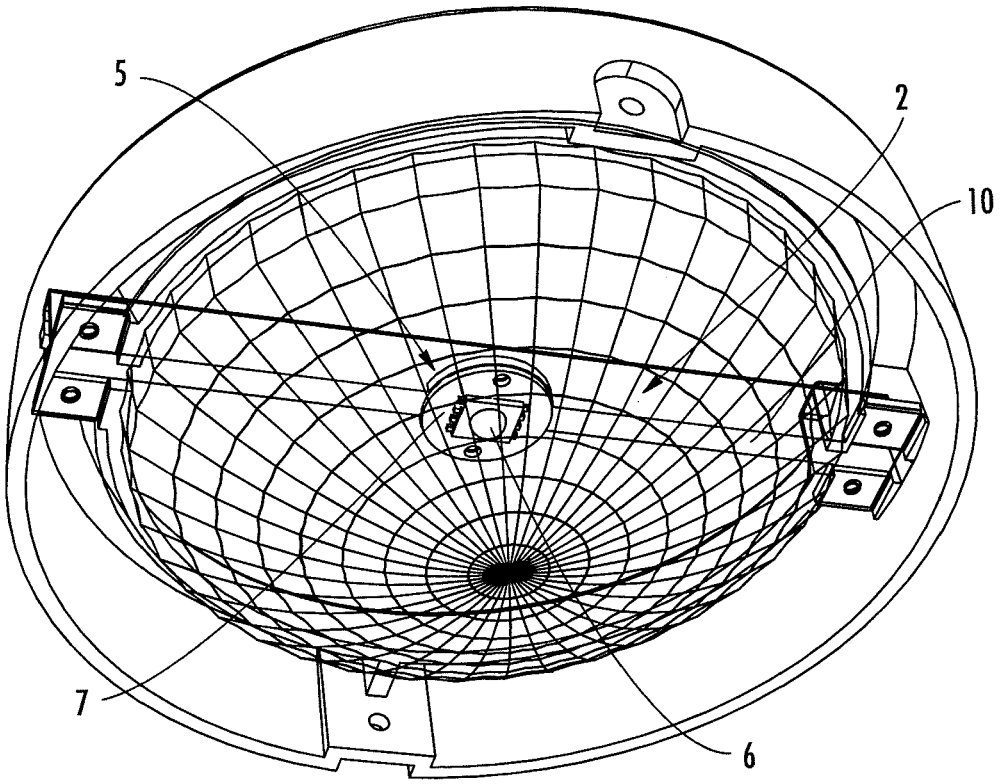


FIG. 3

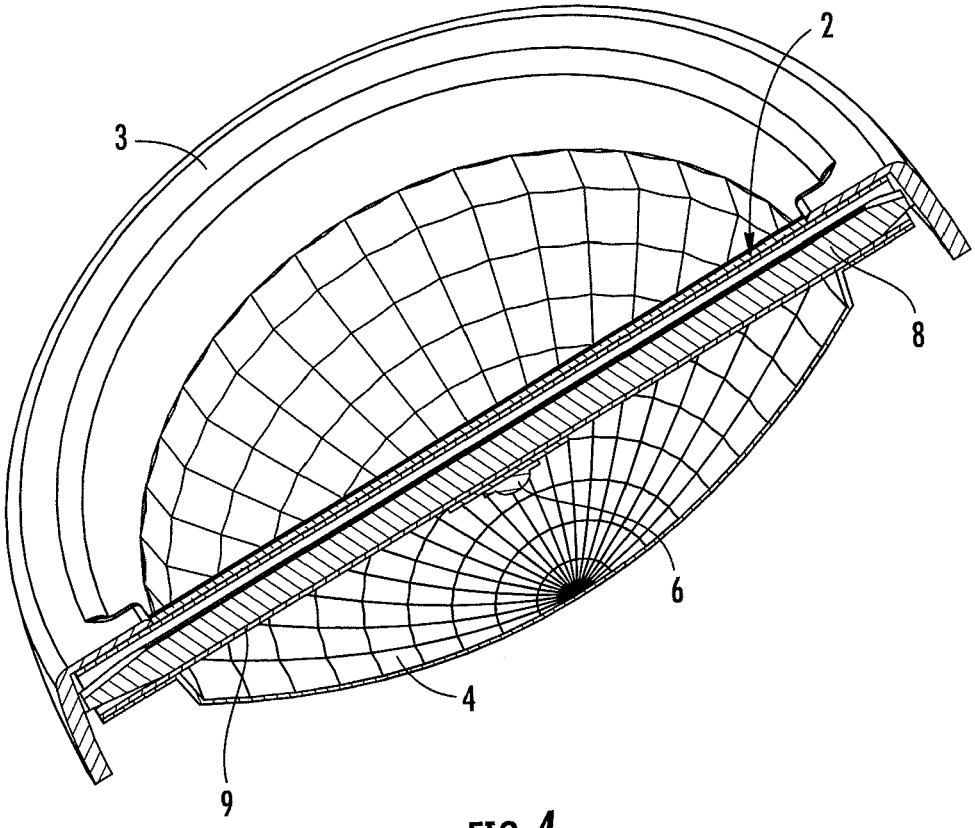


FIG. 4

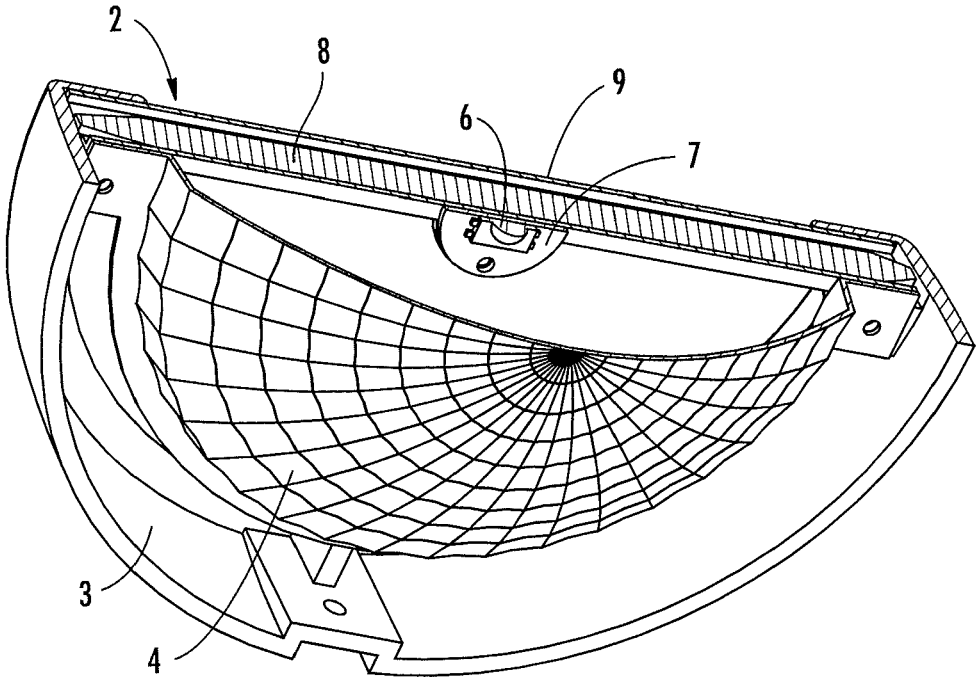
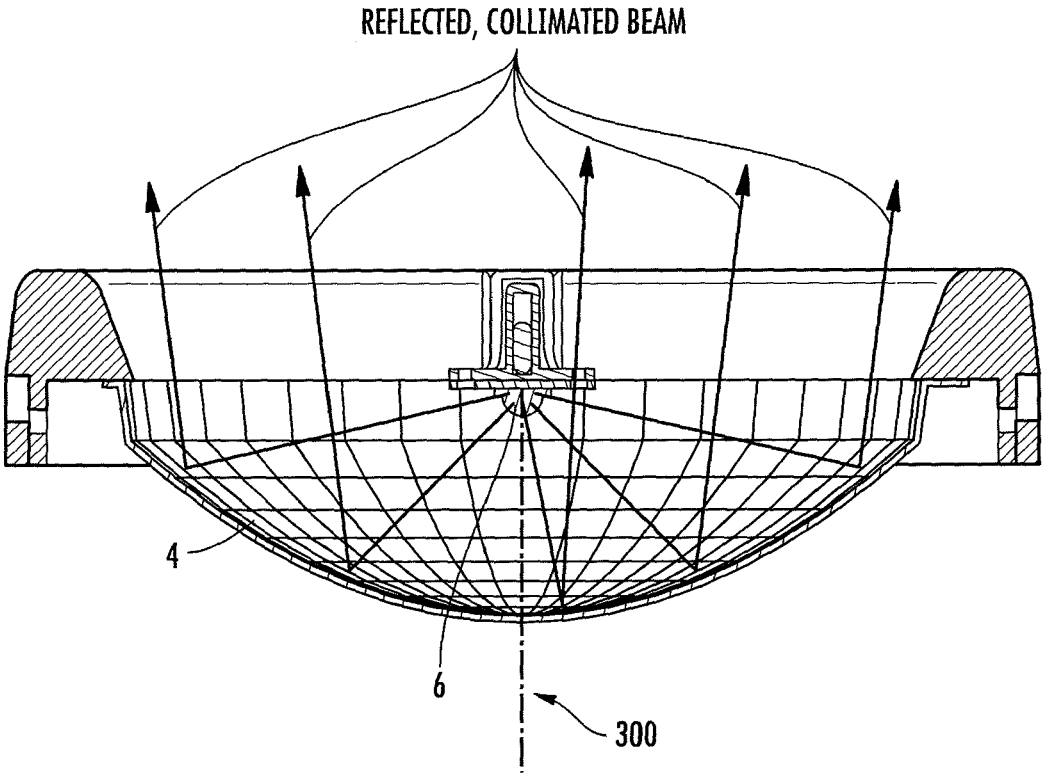


FIG. 5



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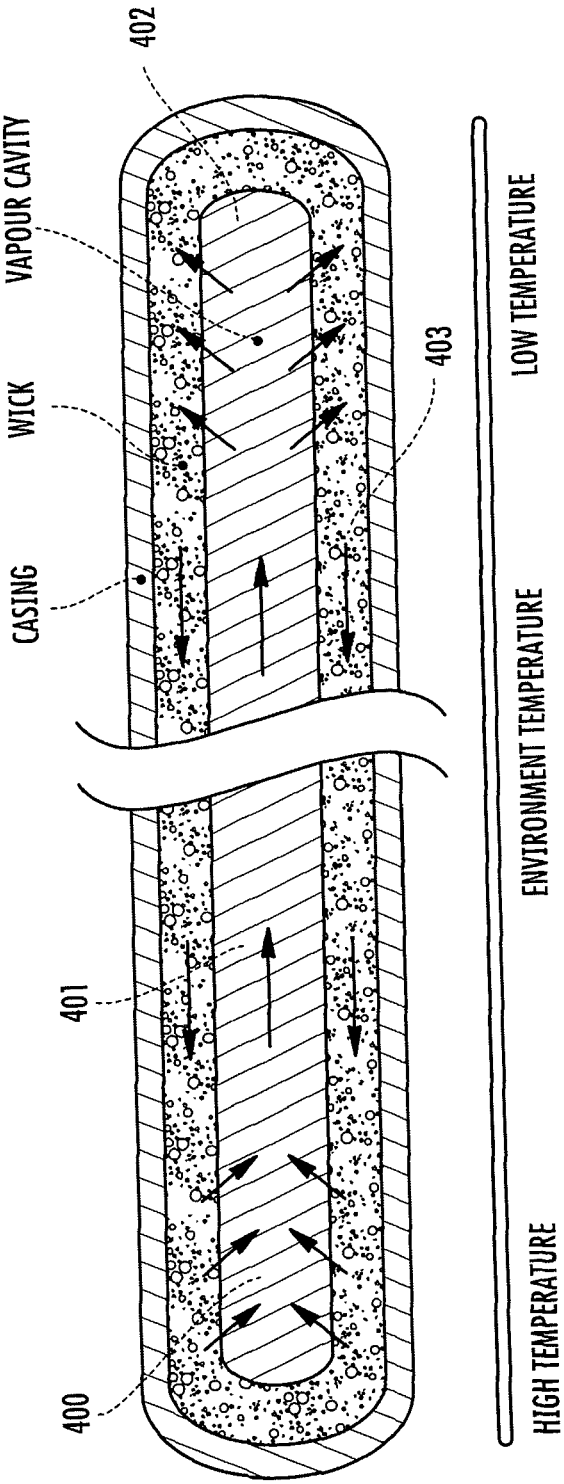


FIG. 7
PRIOR ART

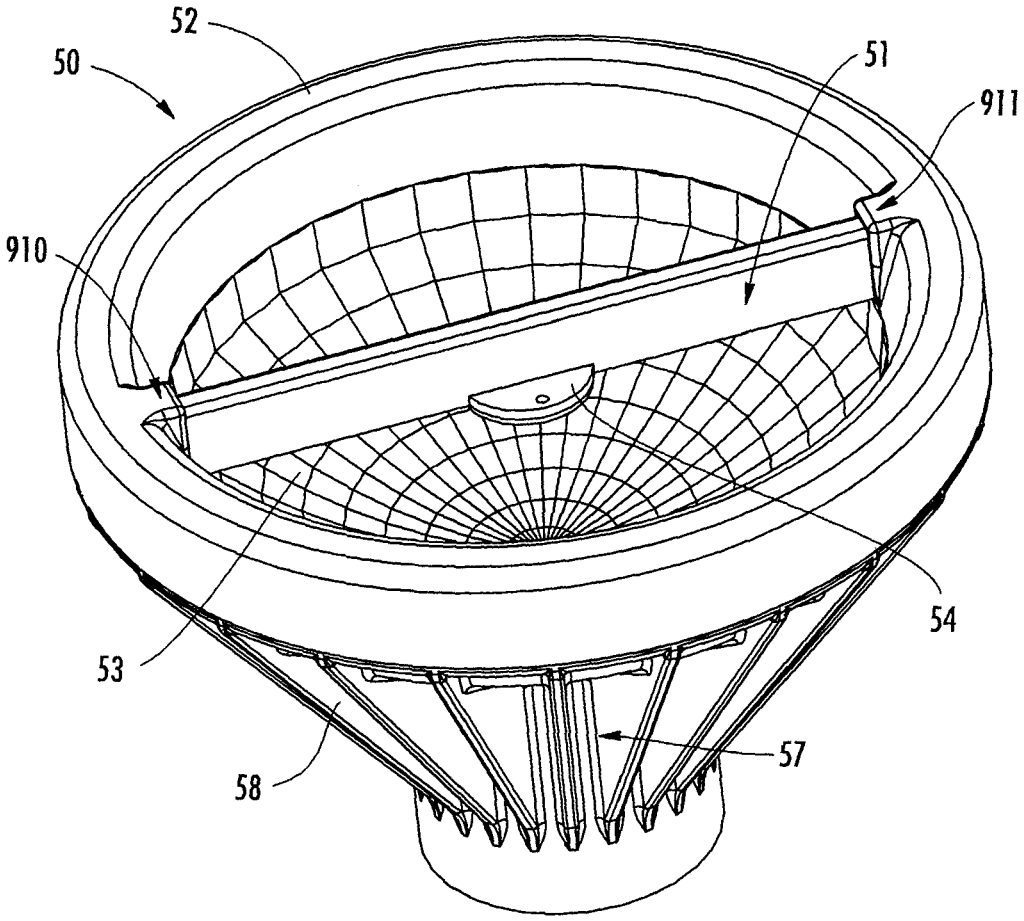


FIG. 8

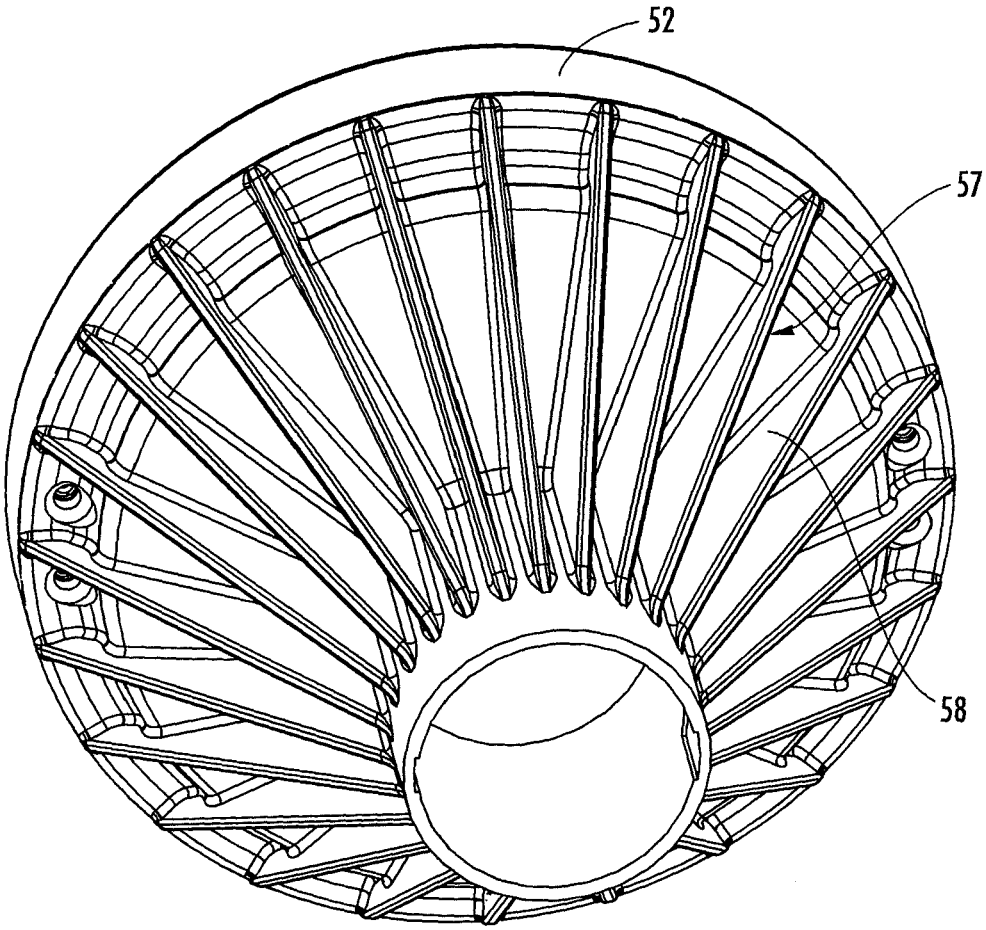
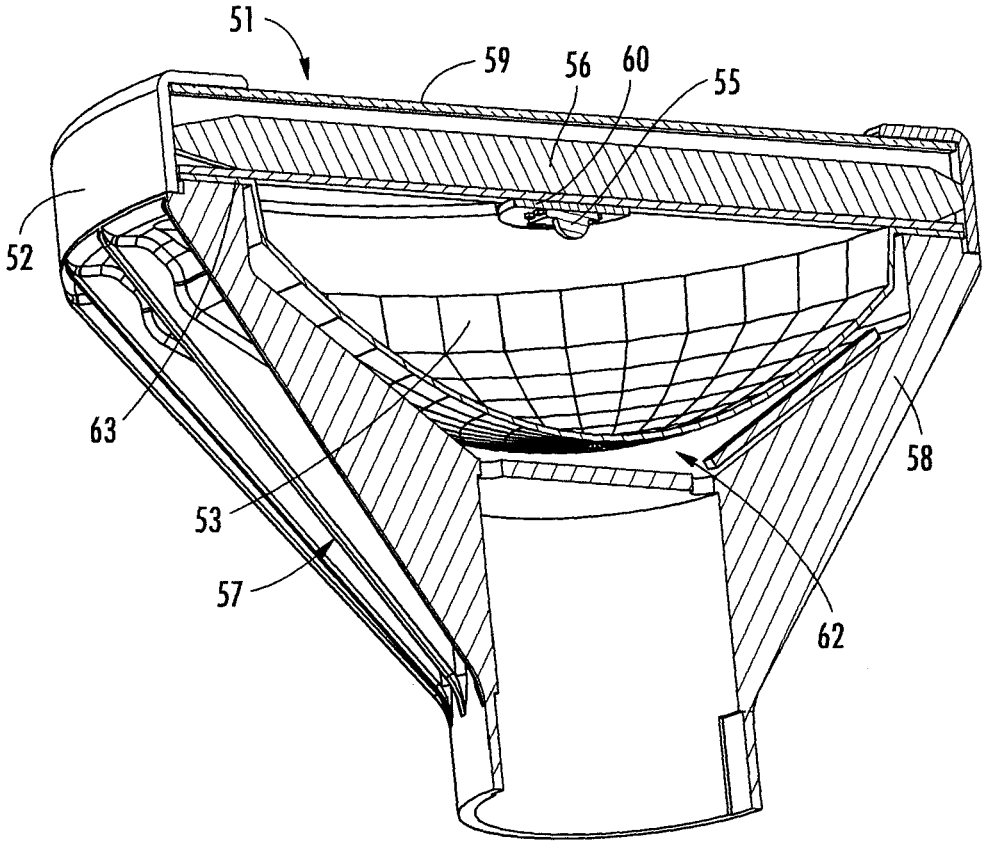


FIG. 9



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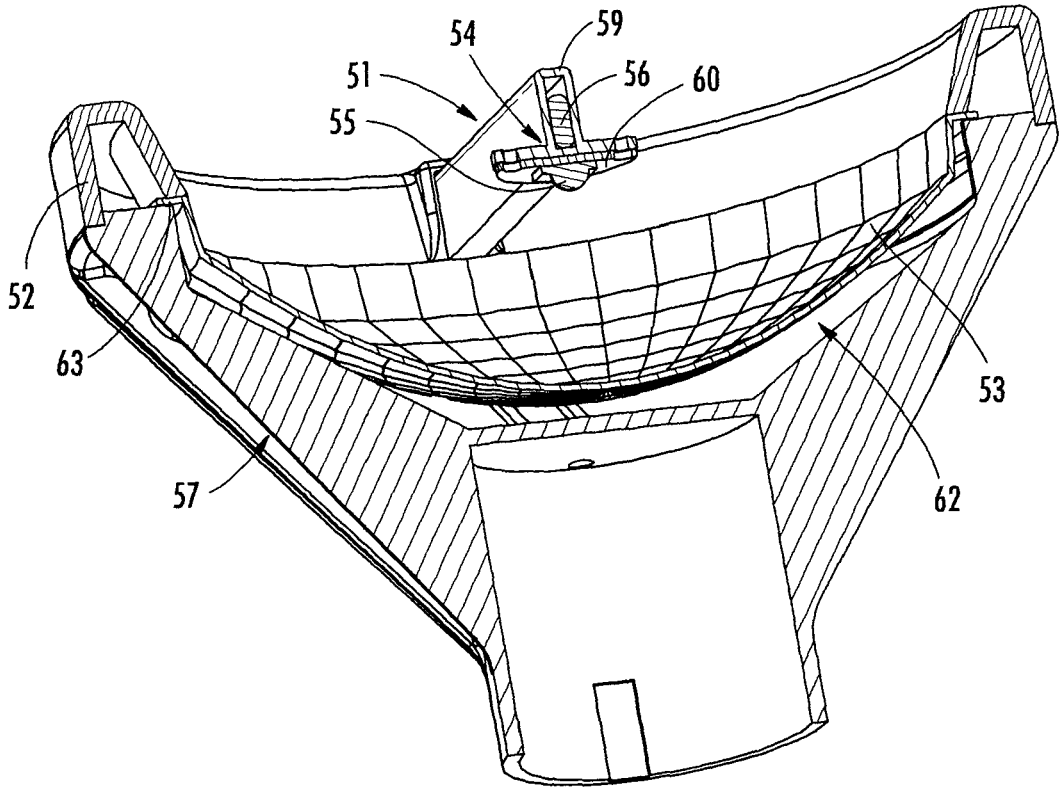
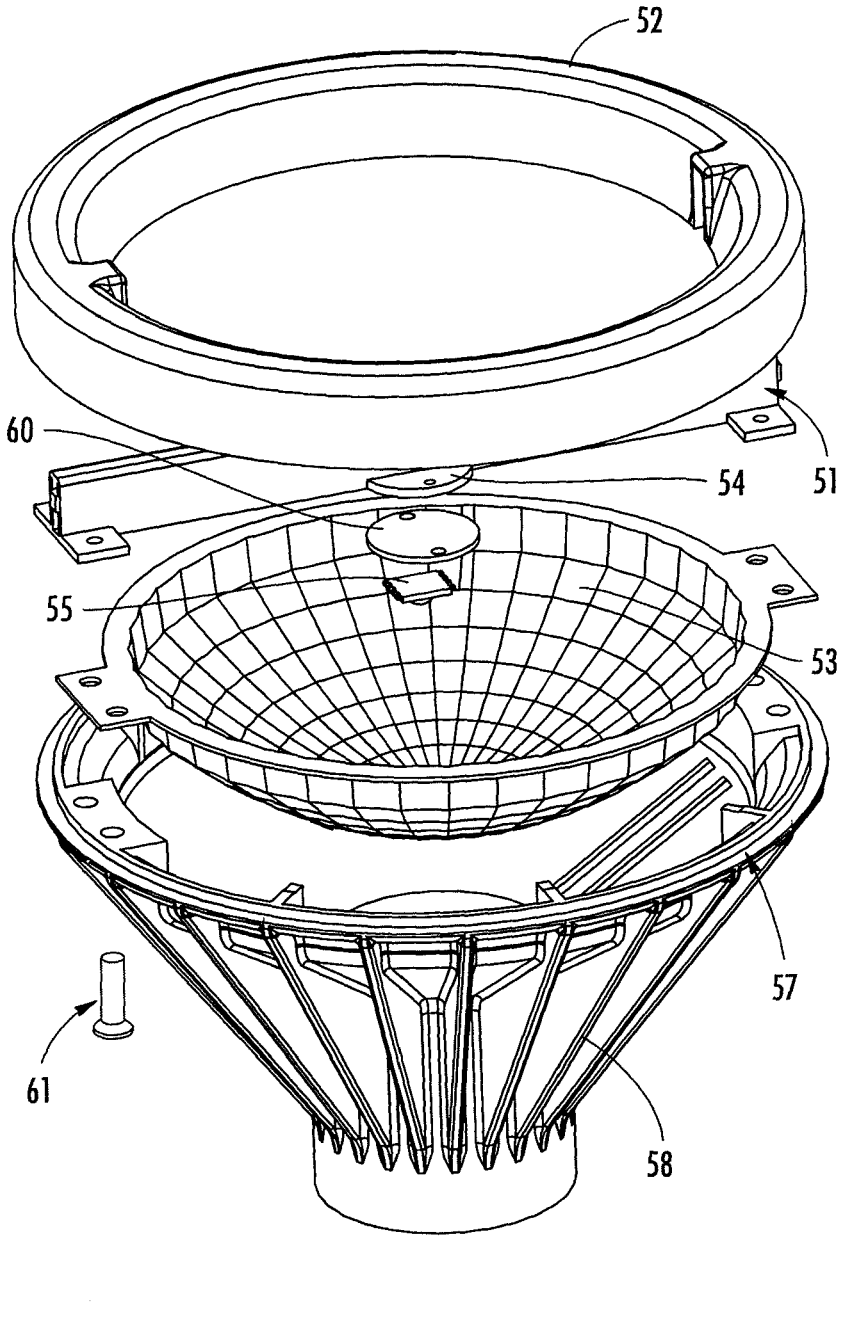


FIG. 11

FIG. 12



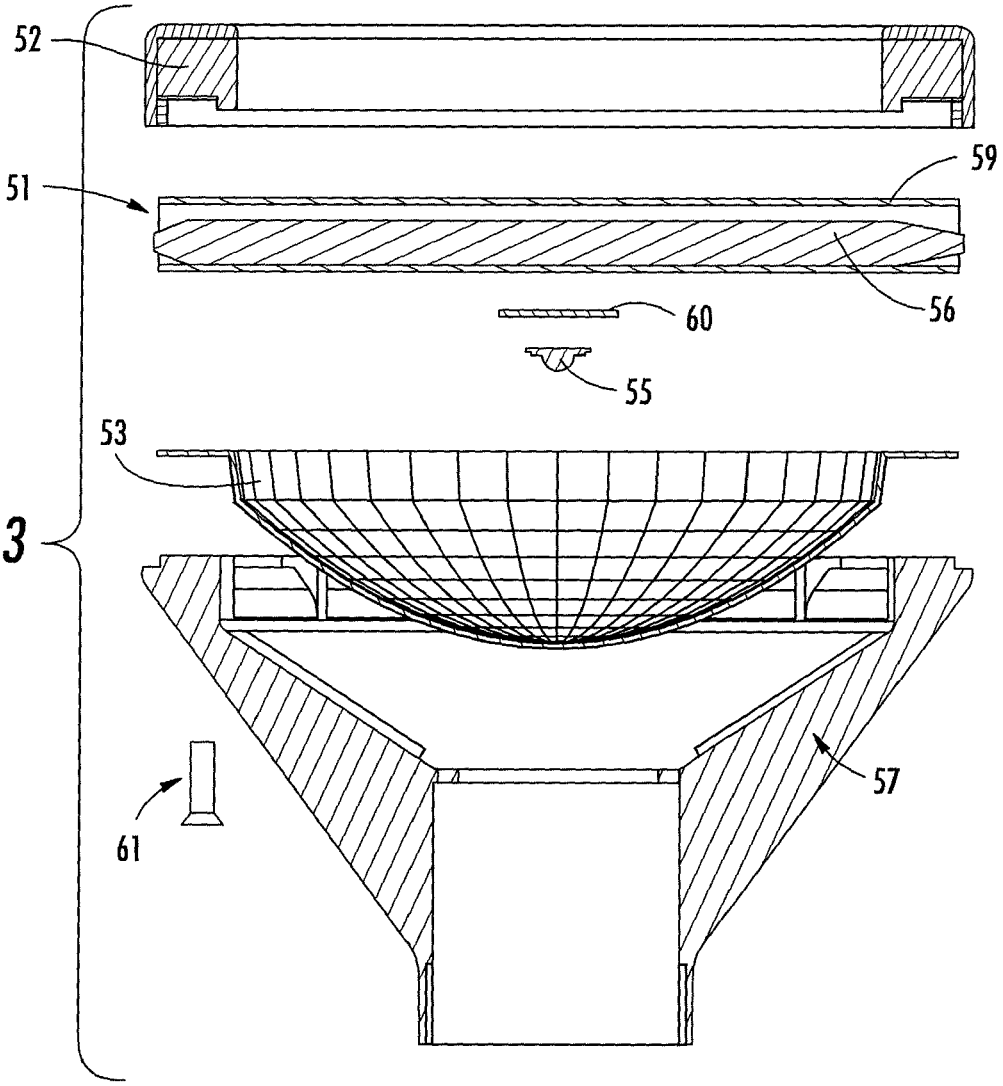
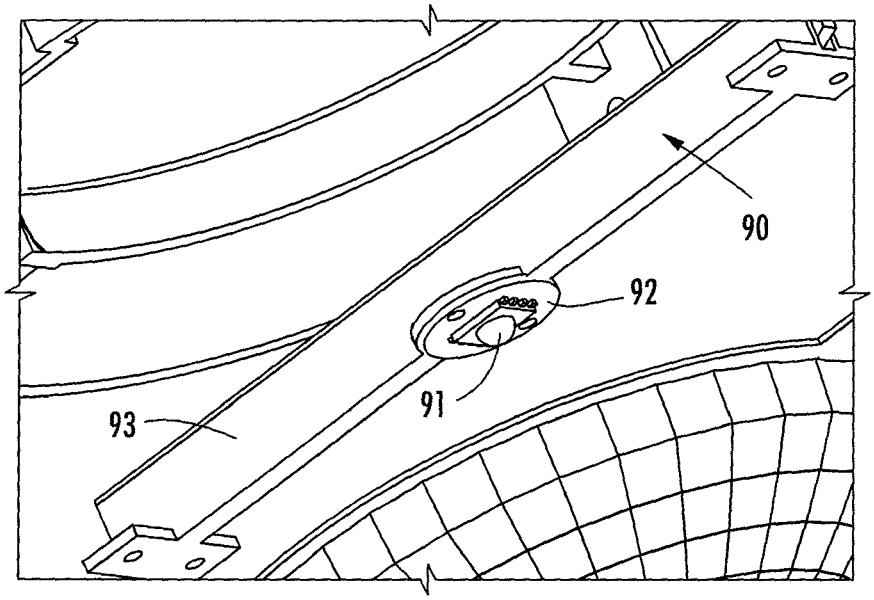


FIG. 13



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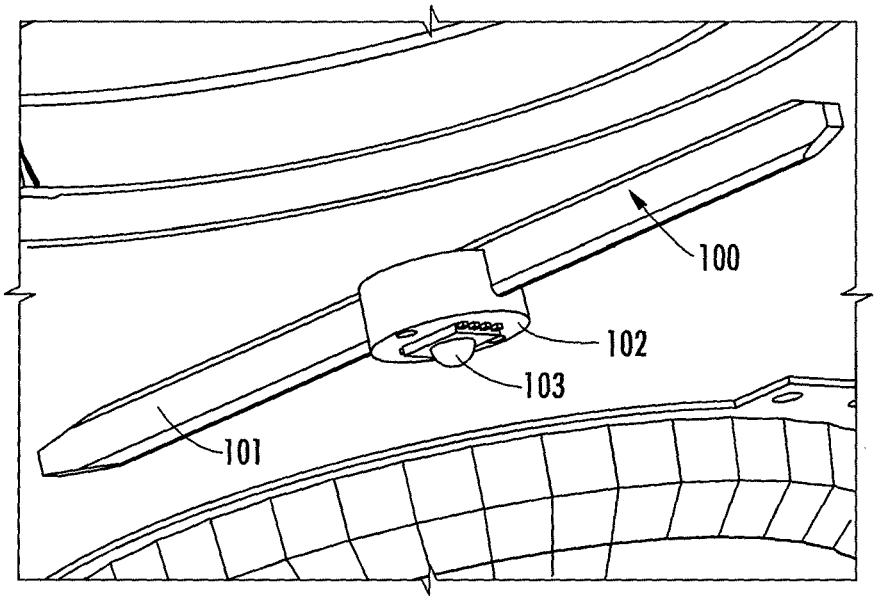

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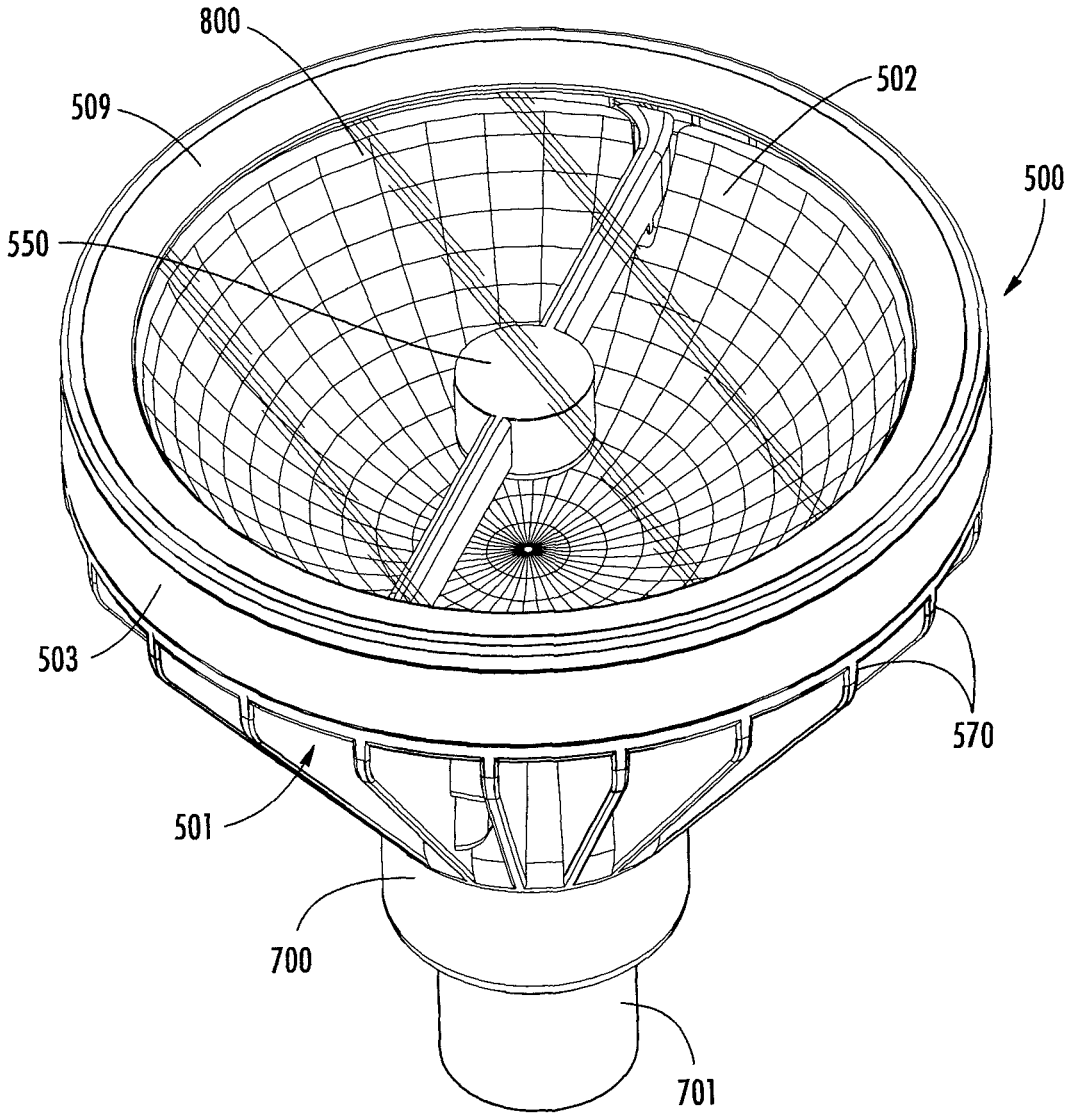

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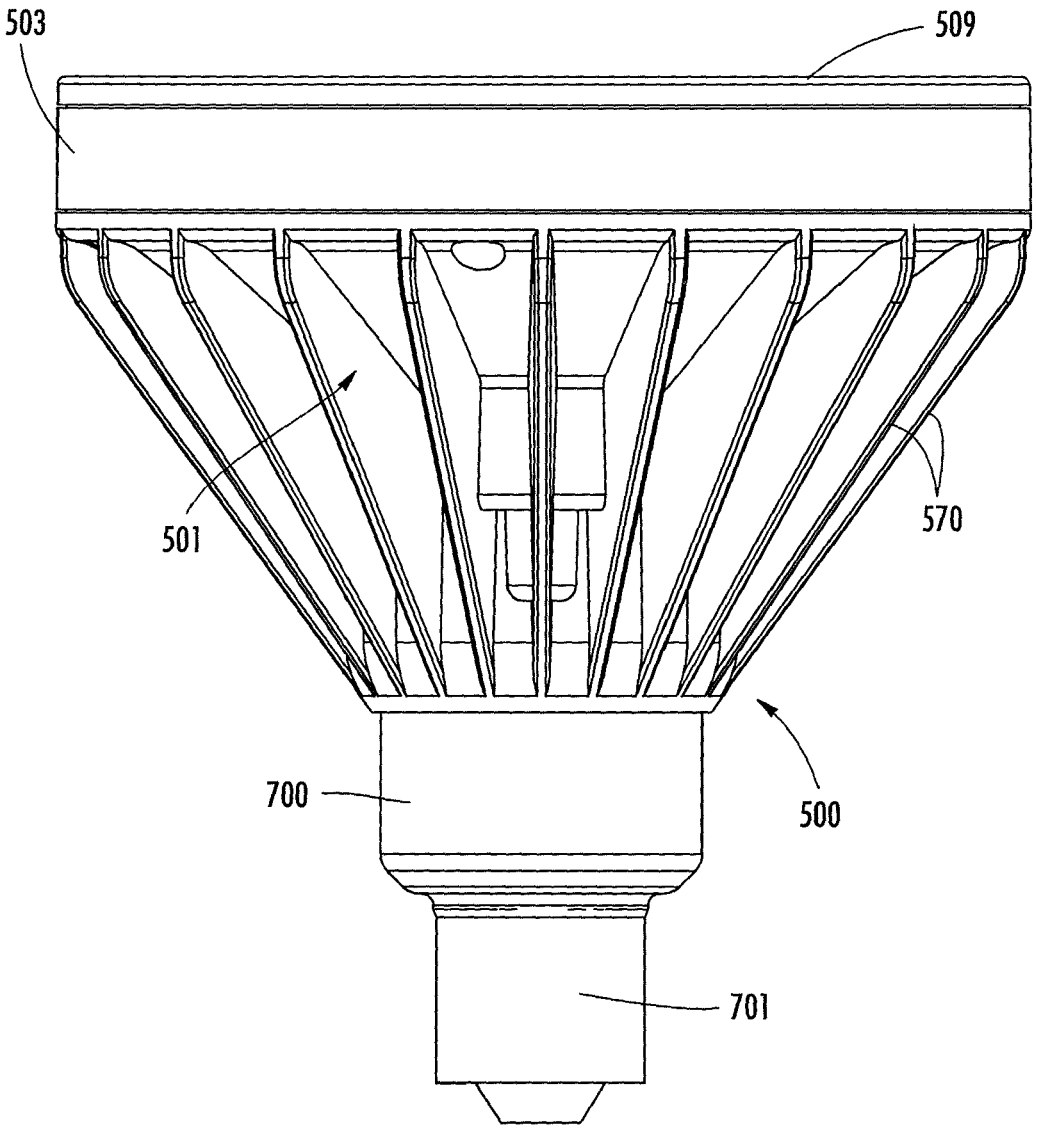


FIG. 17

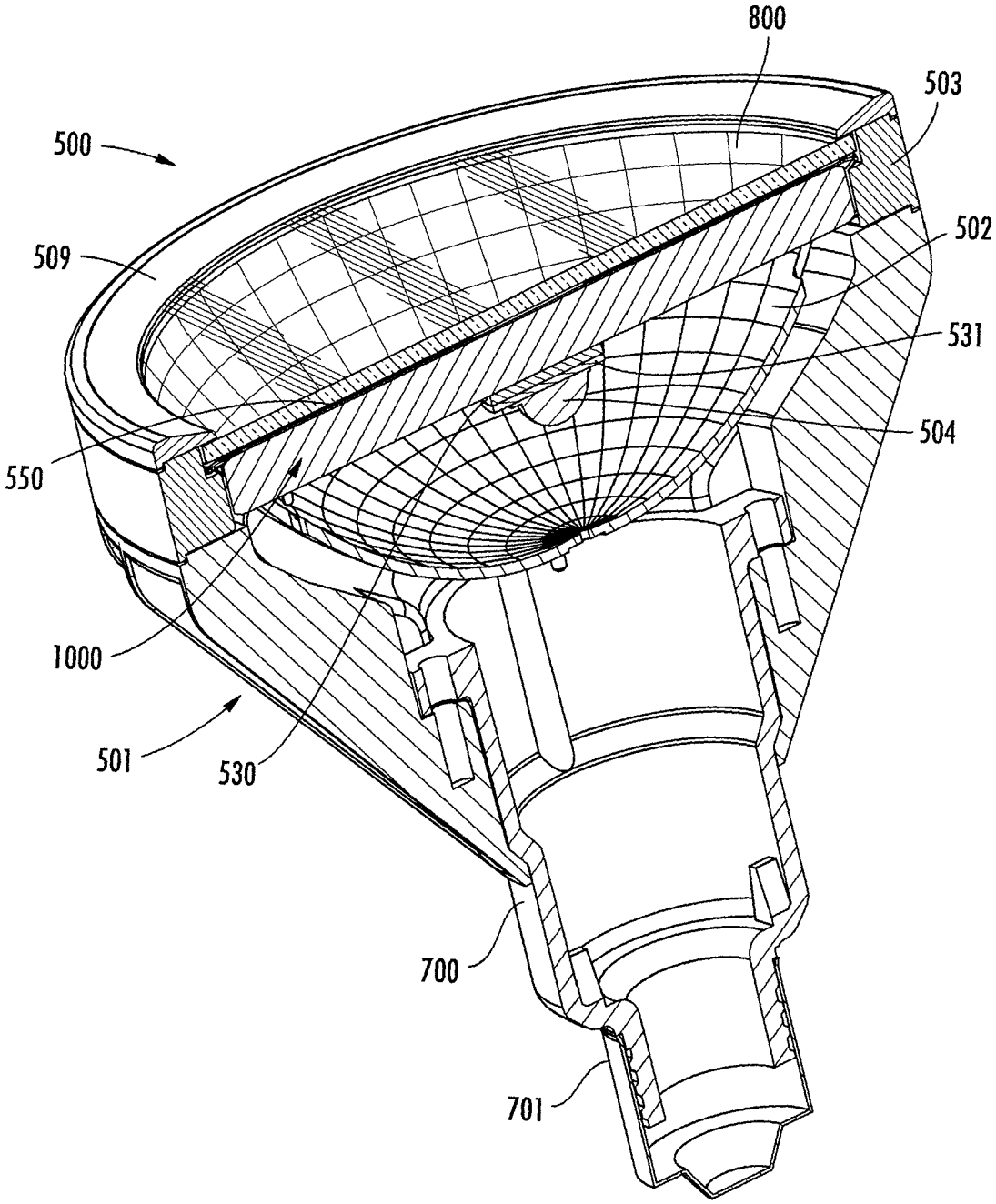


FIG. 18

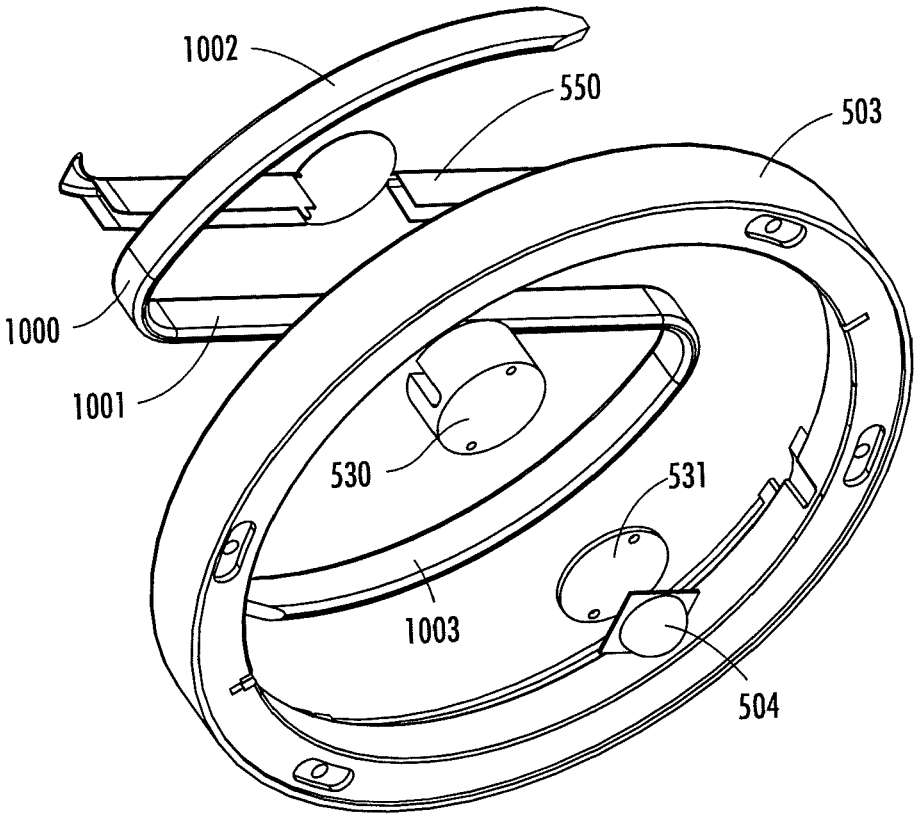


FIG. 19

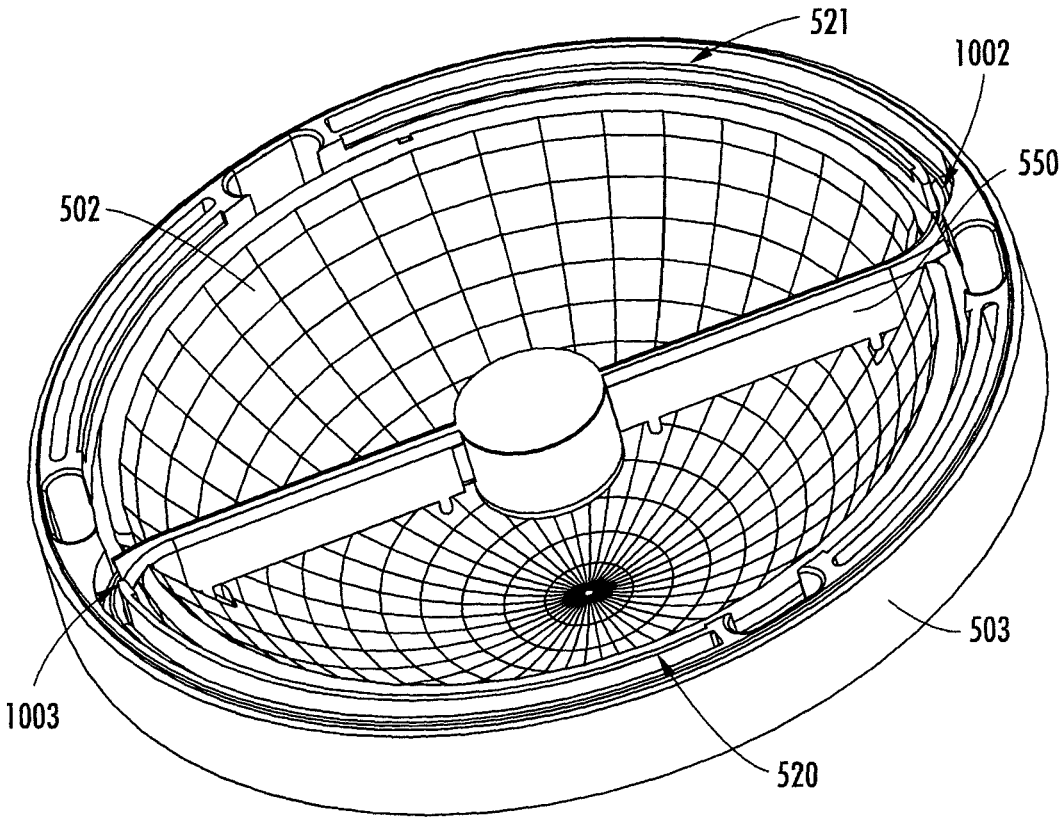


FIG. 20

FIGURE 21

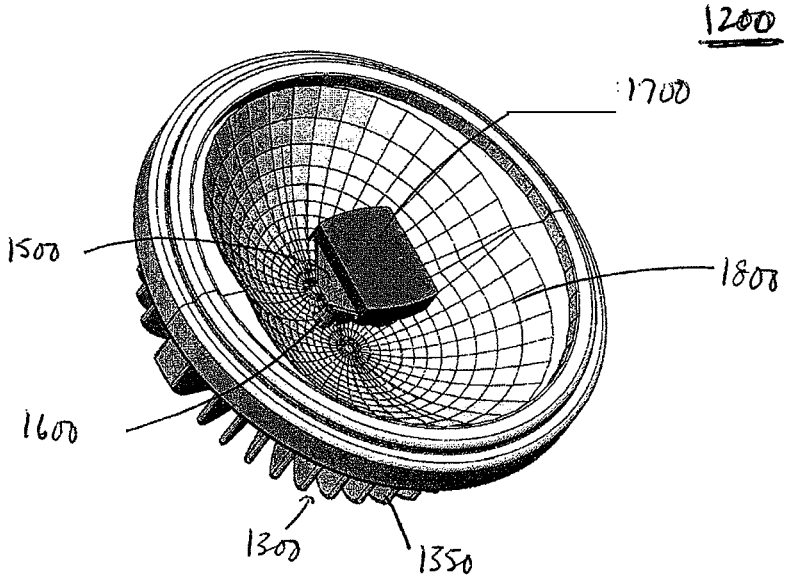


FIGURE 22

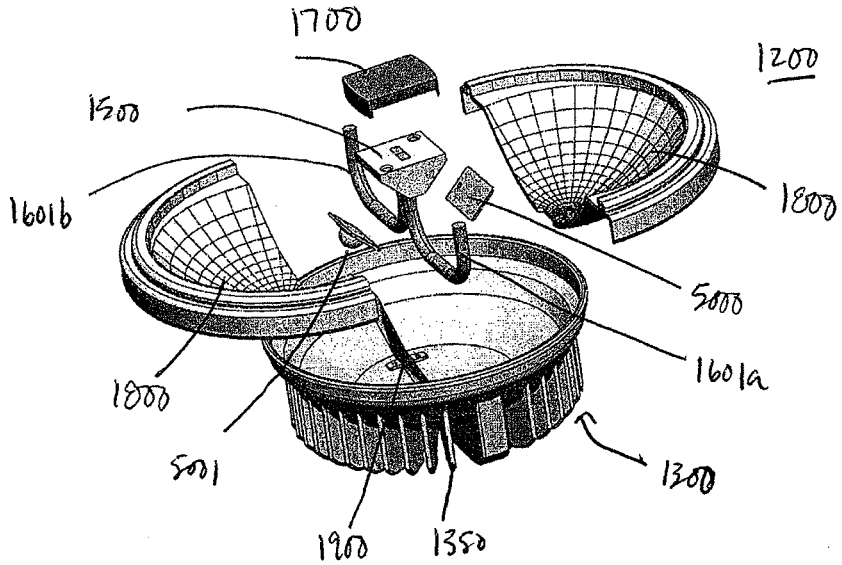


FIGURE 23

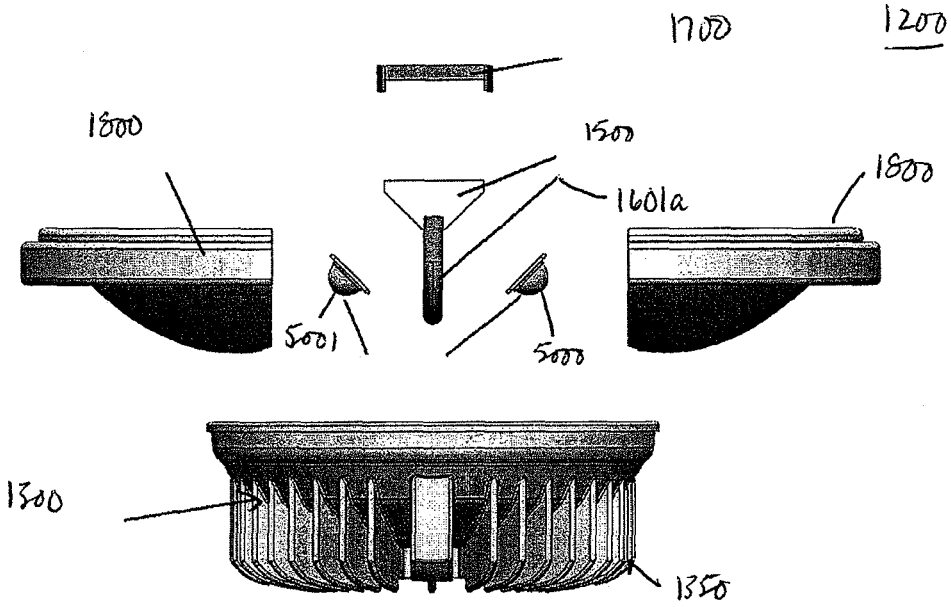


FIGURE 24

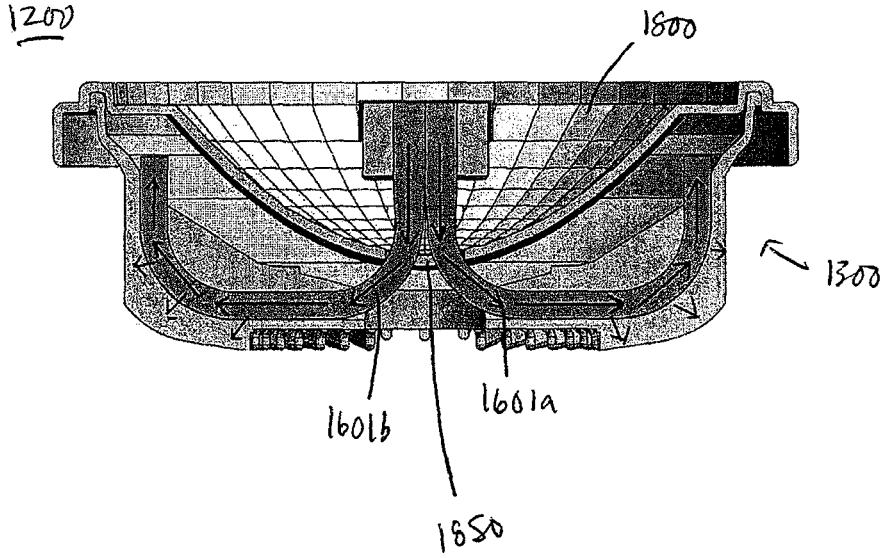


FIGURE 25

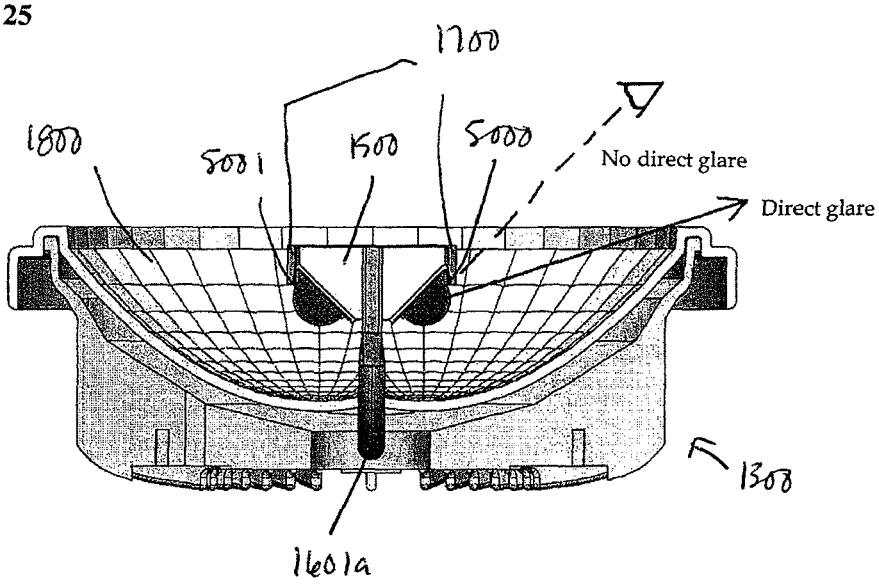


FIGURE 26

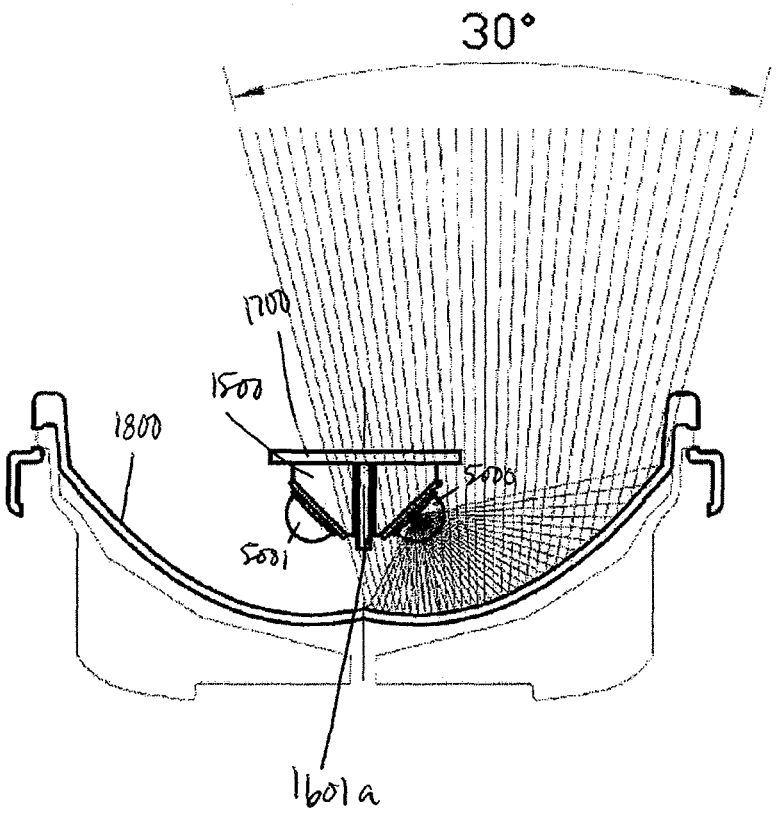


FIGURE 27

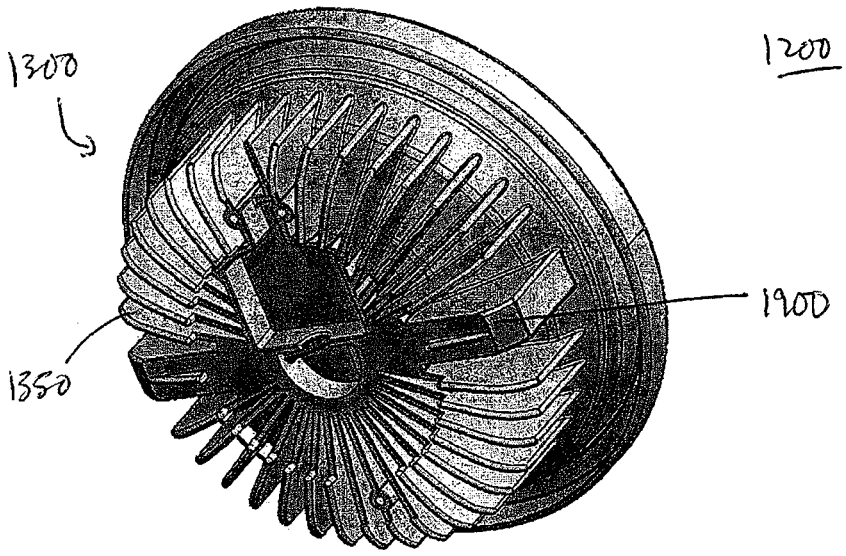


FIGURE 28

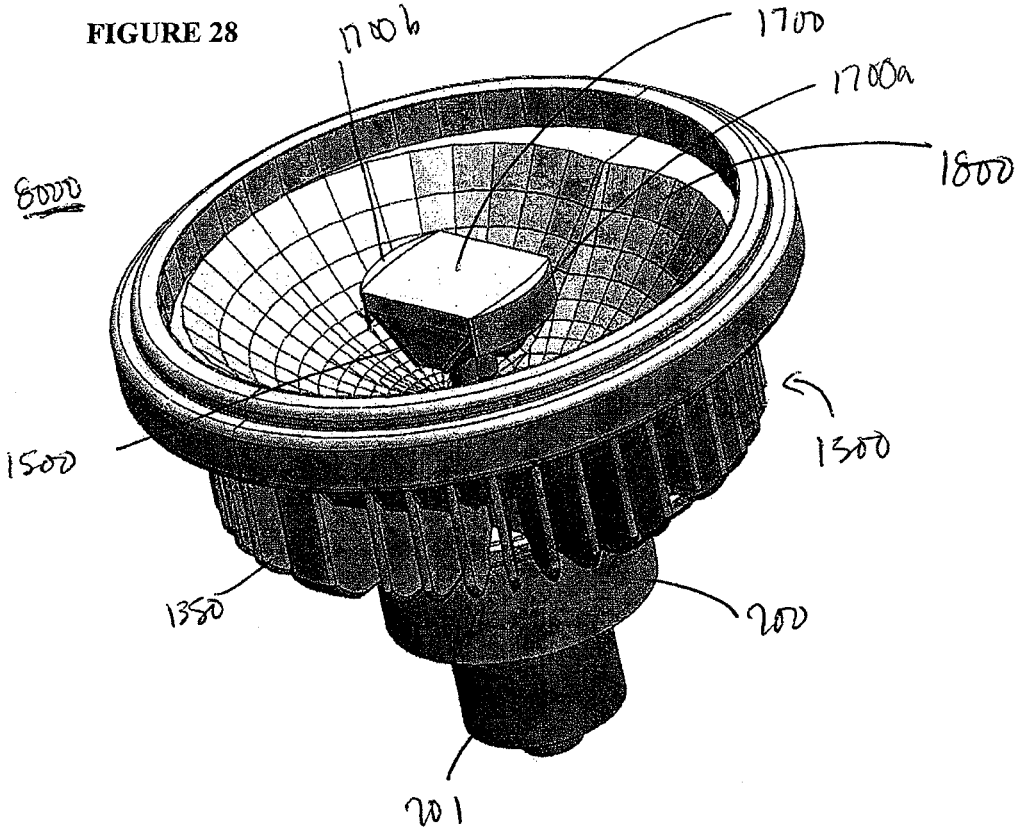


FIGURE 29

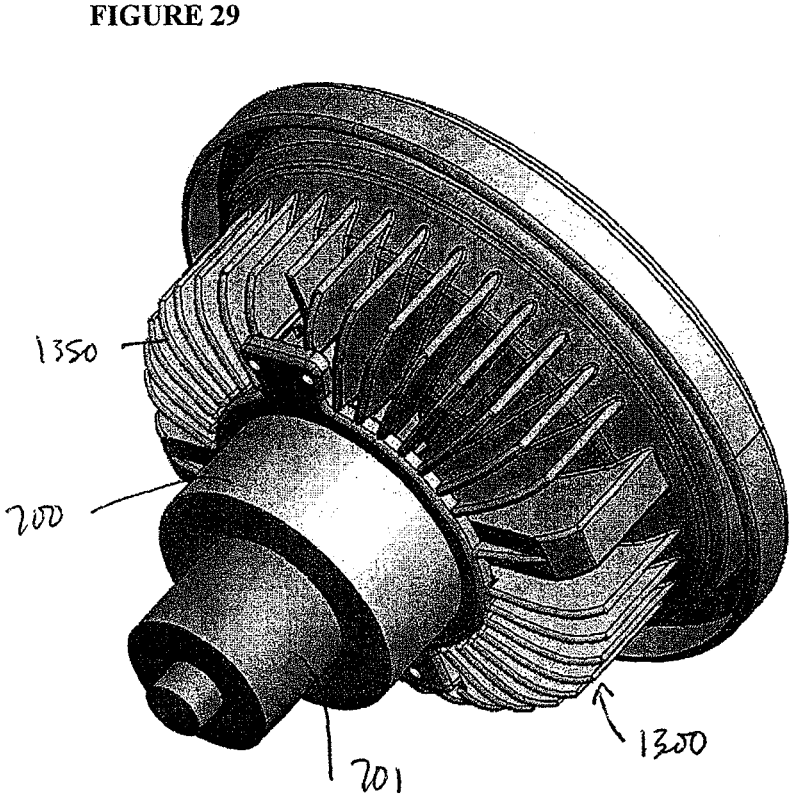


FIGURE 30

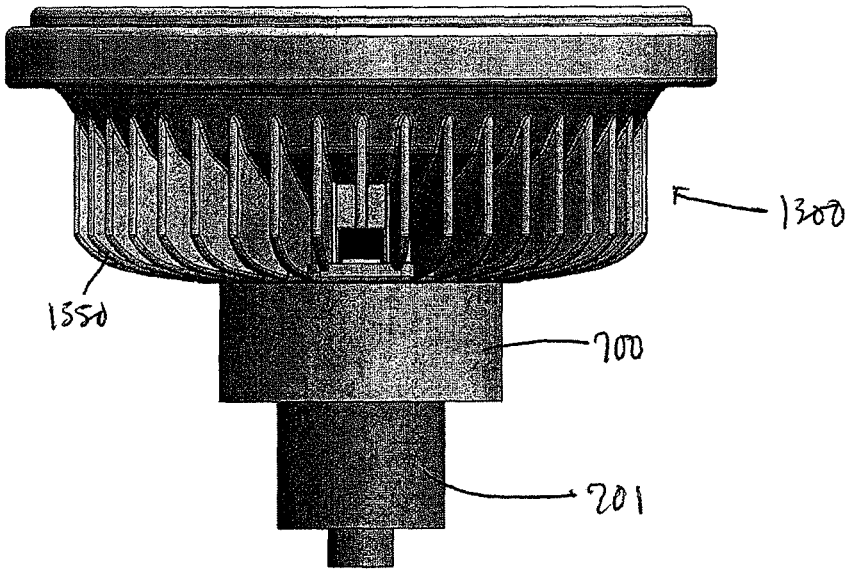
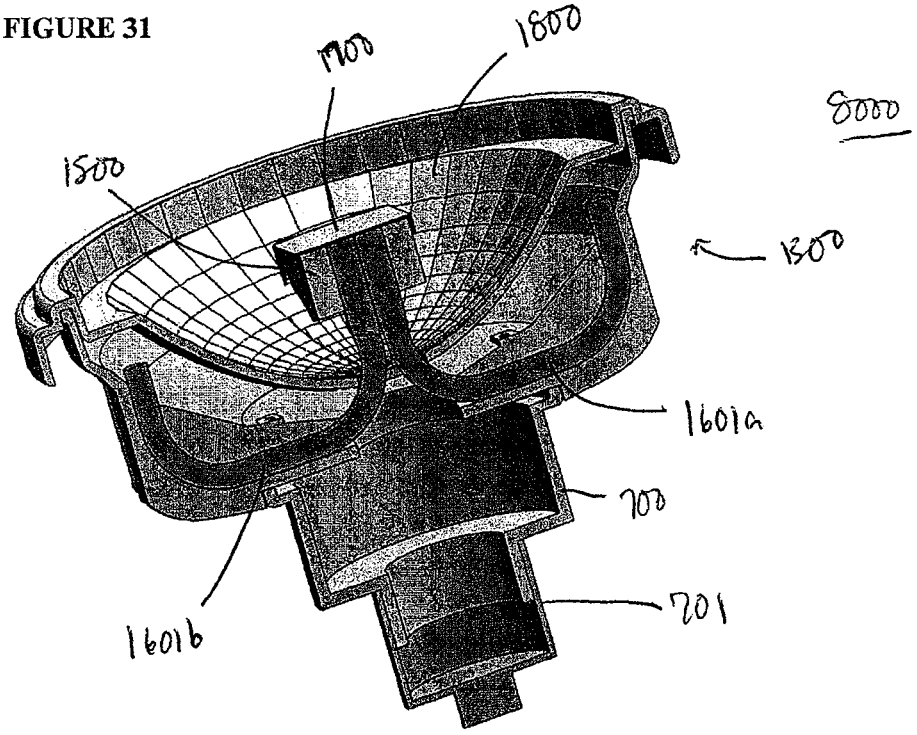


FIGURE 31



NON-GLARE REFLECTIVE LED LIGHTING APPARATUS WITH HEAT SINK MOUNTING

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a utility application which is a continuation-in-part of U.S. Ser. No. 12/470,332, filed May 21, 2009, which claims priority under 35 U.S.C. §119(e) to U.S. Provisional Patent Application Ser. No. 61/055,858, filed May 23, 2008, U.S. Provisional Patent Application Ser. No. 61/057,289, filed May 30, 2008, and U.S. Provisional Patent Application Ser. No. 61/118,202, filed Nov. 26, 2008, the entirety of which are incorporated herein by reference.

Throughout this application, several patents and references are referenced. Disclosure of these patents and references in their entirety is hereby incorporated by reference into this application.

FIELD OF THE INVENTION

The present invention relates to electrical lighting devices and systems and, more specifically, lighting apparatuses using at least one single-chip or multi-chip light-emitting diode ("LED"), back-reflecting collection optics for LEDs, and an improved heat sink mounting apparatus which promotes efficient heat dissipation generated from the LED while minimizing light obstruction and glare.

BACKGROUND OF THE INVENTION

For years, people have used traditional incandescent or fluorescence lighting apparatuses in order to address their interior lighting concerns. However, such lighting apparatuses present a number of drawbacks. For example, the popular AR111 halogen apparatus presents the following drawbacks—relatively high power consumption, inefficiency of light dispersion due to the placement of its metal shield in the line sight of the halogen bulb, and its limited effectiveness in preventing glare from the halogen bulb.

Recently, a number of LED lighting apparatuses have been designed to replace the AR111 halogen apparatus, as well as other traditional incandescent or fluorescence lighting apparatuses. Typically, in such LED lighting apparatuses, the LED light source is located at the center of a reflector with its light emission directed outward from the reflector. Additionally, there are LED lighting apparatuses, such as PAR38, which use multiple LEDs with their light emissions directed outward from one or more reflectors. These configurations are unable to achieve narrow beam angles, and result in considerable glare since observers are not shielded from the LED light source. Further, these configurations inefficiently distributes heat; thereby, making the use of high-powered LEDs in these configurations practically prohibitive.

To address these problems, alternative LED lighting apparatuses which use a mirror or reflective surface to reflect light back in the direction of the LED light source have been disclosed. See, e.g., U.S. Pat. No. 6,976,769 to McCullough et al. entitled "Light-Emitting Diode Reflector Assembly Having a Heat Pipe," U.S. Pat. No. 7,246,921 to Jacobson et al. entitled "Back-Reflecting LED Light Source", and PCT International Publication No. WO 2006/033998 to Magna International Inc. entitled "Thermal Management System for Solid State Automotive Lighting."

SUMMARY OF THE INVENTION

In light of the above, there exists a need to further improve the art. Specifically, there is a need for an LED lighting apparatus that eliminates or reduces glare, and has an improved, compact thermally-conductive assembly which promotes efficient heat dissipation generated from the LED (such as a high-powered LED) while minimizing obstruction of the light path and the number of components needed in such assembly.

In accordance with an aspect of the present invention, a lighting apparatus comprises a main housing; a reflector disposed within the main housing, the reflector having a front side and a rear side; a heat conducting body comprising at least two heat pipes, wherein a first portion of the at least two heat pipes are positioned parallel to a central axis of the lighting apparatus on the front side of the reflector, and a second portion of each of the at least two heat pipes is in the rear side of the reflector and is thermally coupled to the main housing; a heat conducting head located on the front side of the reflector, and is thermally coupled to the heat conducting body; at least two LEDs thermally coupled to the heat conducting head and the heat conducting body, the at least two LEDs being positioned to face the front side of the reflector so that light emitted from the at least two LEDs are directed to the front side of the reflector.

In accordance with another aspect of the present invention, the at least two heat pipes are substantially J-shaped, L-shaped, or a combination thereof.

In accordance with another aspect of the present invention, the heat conducting body provides a pathway for heat to flow from the at least two LEDs toward the main housing.

In accordance with another aspect of the present invention, the reflector has at least two central optical axes.

In accordance with another aspect of the present invention, one end of the heat conducting body is thermally coupled to the at least two LEDs, and the other end of the heat conducting body is thermally coupled to the main housing.

In accordance with another aspect of the present invention, the reflector is in a symmetrical or unsymmetrical shape.

In accordance with another aspect of the present invention, the main housing is substantially frustoconical, cylindrical or cubical in shape, and is made of a thermally-conductive material.

In accordance with another aspect of the present invention, the main housing comprises one or more heat dissipating fins.

In accordance with a further aspect of the present invention, the lighting apparatus further comprises a plastic housing, coupled to the main housing; and a lamp base coupled to the plastic housing.

In accordance with another aspect of the present invention, the lamp base is an E26 lamp base, a GU10 lamp base, an E27 lamp base, or a GU24 lamp base.

In accordance with a further aspect of the present invention, the lighting apparatus further comprises the at least two LEDs being positioned at a range of 0 degree to 120 degrees relative to the central axis of the lighting apparatus.

In accordance with another aspect of the present invention, the heat conducting head has a triangular side profile or an irregular hexagon side profile, and has at least two mounting areas for the at least two LEDs, respectively.

In accordance with another aspect of the present invention, the heat conducting head is made of aluminum, copper, or a combination thereof.

In accordance with another aspect of the present invention, the lighting apparatus further comprises a PCB coupled the at least two LEDs and the heat conducting head.

According to another aspect of the present invention the lighting apparatus comprises a main housing having a generally frustoconical shape; a reflector disposed within the main housing, the reflector having a front side, a rear side and at

least two central optical axes; a heat conducting body comprising at least two substantially J-shaped heat pipes, wherein a first portion of the at least two substantially J-shaped heat pipes is bar-shaped and located on the front side of the reflector, and is coupled to a heat conducting head located at or near a central axis of the lighting apparatus, a second portion of the at least two substantially J-shaped heat pipes which goes through the reflector via an opening at or near the central axis of the lighting apparatus, and a third portion of the at least two substantially J-shaped heat pipes is curved and at least a portion of which is coupled to the main housing; and at least two LEDs thermally coupled to the heat conducting head and positioned facing the front side of the reflector at an inclined angle relative to a central axis of the lighting apparatus so that light emitted from the at least two LEDs are directed to the front side of the reflector.

In accordance with a further aspect of the present invention, the lighting apparatus further comprises an anti-glare cap coupled to the heat conducting head.

BRIEF DESCRIPTION OF THE DRAWINGS

For the purposes of illustrating the present invention, the drawings reflect a form which is presently preferred; it being understood however, that the invention is not limited to the precise form shown by the drawings in which:

FIG. **1** is a perspective view from the top side of a lighting apparatus according to an aspect of the present invention;

FIG. **2** is a perspective view from the bottom side of the lighting apparatus shown in FIG. **1**;

FIG. **3** is an "X-ray" view from the bottom side of the lighting apparatus shown in FIG. **3**;

FIG. **4** is a cross-sectional perspective view from the top side of the lighting apparatus shown in FIG. **1**;

FIG. **5** is a cross-sectional perspective view from the bottom side of the lighting apparatus shown in FIG. **1**;

FIG. **6** is a cross-sectional view of the lighting apparatus shown in FIG. **1**;

FIG. **7** is a cross-sectional view of a known heat pipe (from http://en.wikipedia.org/wiki/Image:Heat_Pipe_Mechanism.png);

FIG. **8** is a perspective view of a lighting apparatus according to another aspect of the present invention;

FIG. **9** is a perspective view from the bottom side of the lighting apparatus shown in FIG. **8**;

FIG. **10** is a cross-sectional perspective view of the lighting apparatus shown in FIG. **8**;

FIG. **11** is another cross-sectional perspective view of the lighting apparatus shown in FIG. **8**;

FIG. **12** is an exploded perspective view of the lighting apparatus shown in FIG. **8**;

FIG. **13** is an exploded cross-sectional view of the lighting apparatus shown in FIG. **8**;

FIG. **14** is a perspective view of a heat conducting body (cladded heat pipe) with an LED coupled directly onto according to an aspect of the present invention;

FIG. **15** is a perspective view of a heat conducting body (non-cladded heat pipe) with an LED coupled directly onto according to another aspect of the present invention;

FIG. **16** is a perspective view of a lighting apparatus (which includes an S-shaped heat conducting body) according to another aspect of the present invention;

FIG. **17** is a side view of the lighting apparatus shown in FIG. **16**;

FIG. **18** is a cross-sectional perspective view of the lighting apparatus shown in FIG. **16**;

FIG. **19** is an exploded perspective view of the top rim and a heat sink mounting apparatus (which includes a metal cladding, an S-shaped heat conducting body, a mounting platform, a mounting plate, and an LED) of the lighting apparatus shown in FIG. **16**;

FIG. **20** is a perspective view from the top side (without a glass cover) of the lighting apparatus shown in FIG. **16**;

FIG. **21** is a perspective view from the top side of a lighting apparatus according to another aspect of the present invention;

FIG. **22** is an exploded perspective view from the top side of the lighting apparatus shown in FIG. **21**;

FIG. **23** is an exploded cross-sectional view of the lighting apparatus shown in FIG. **21**;

FIG. **24** is a cross-sectional view of the lighting apparatus shown in FIG. **21**;

FIG. **25** is another cross-sectional view of the lighting apparatus shown in FIG. **21**;

FIG. **26** is a cross-sectional view of the lighting apparatus shown in FIG. **21**;

FIG. **27** is a perspective view from the bottom side of the lighting apparatus shown in FIG. **21**;

FIG. **28** is a perspective view of a lighting apparatus according to another aspect of the present invention;

FIG. **29** is a perspective view from the bottom side of the lighting apparatus shown in FIG. **28**;

FIG. **30** is a side view of the lighting apparatus shown in FIG. **28**; and

FIG. **31** is a cross-sectional perspective view of the lighting apparatus shown in FIG. **28**.

DETAILED DESCRIPTION OF THE INVENTION

As shown in FIGS. **1-6**, and in accordance with an aspect of the present invention, a lighting apparatus **1** has a reflector **4** which is coupled to a top rim **3**, wherein the top rim **3** is coupled to a heat conducting body **2**. The heat conducting body **2** contains a heat pipe **8** which is cladded by a cladding **9**, and a mounting platform **5** located on one side of the heat conducting body **2** facing opposite the front side of the reflector **4**. As shown in FIG. **3**, an LED **6** is coupled to a metal core printed circuit board ("PCB") **7** which is then coupled to the mounting platform **5**. The mounting platform **5** is shaped (which, in this aspect of the present invention, is circular) in such a manner that it provides increased non-glare protection from the LED relative to existing lighting apparatuses.

In this aspect of the present invention, the LED **6** is located above at or near a central optical axis **300** of the reflector **4**, and is positioned so that light emitted from the LED **6** is substantially or entirely directed to the front side of the reflector **4**; thereby, as shown in FIG. **6**, allowing the reflector **4** to collect and colliminate the light emitted from LED **6**, and reflect the colliminated light away from the reflector **4** and past LED **6** and the heat conducting body **2**. The heat conducting body **2** intercepts very little of the exiting reflected, colliminated light from reflector **4** due to its flat, narrow construction. As shown in FIG. **3**, the flat, narrow construction of the heat conducting body **2** creates a small cross-section **10** to the exiting reflected, colliminated light from reflector **4**.

In this aspect of the present invention, the heat generated from the LED **6** travels the following heat path through the lighting apparatus: metal core PCB **7**, mounting platform **5**, cladding **9**, heat pipe **8**, cladding **9**, and then top rim **3** and reflector **4**. The heat generated from the LED **6** can also travel through metal core PCB **7**, mounting platform **5**, cladding **9**,

heat pipe **8**, and then top rim **3** and reflector **4**. The top rim **3** and reflector **4** act as heat sinks.

Another aspect of the present invention is shown in FIGS. **8-13**. Specifically, the lighting apparatus **50** contains a reflector **53** which is coupled to a top rim **52**, wherein the top rim **52** is coupled to a heat conducting body **51**. The heat conducting body **51** contains a heat pipe **56** which is cladded by a cladding **59**, and a mounting platform **54** located on one side of the heat conducting body **51** facing opposite the reflector **53**. The LED **55**, as shown in FIG. **11**, is coupled to a metal core PCB **60** which is then coupled to the mounting platform **54**.

This aspect of the present invention includes a main housing **57** which has one or more heat dissipating fins **58** for maximizing surface area; thereby, increasing its heat dissipation capacity. The top rim **52**, reflector **53**, and the main housing **57** act as heat sinks, with the main housing **57** acting as the primary heat sink.

As shown in FIGS. **10** and **11**, the main housing **57** is coupled to a reflector edge **63**. There is an air gap **62** between the reflector **53** and the main housing **57**, as shown in FIGS. **10** and **11**. The size of air gap **62** can vary depending on the size of the reflector **53**. The heat generated from the LED **55** travels a heat path which includes travelling through metal core PCB **60**, mounting platform **54**, cladding **59**, heat pipe **56**, cladding **59**, and then top rim **52**, reflector **53** and main housing **57**. The heat can also travel through metal core PCB **60**, mounting platform **54**, cladding **59**, heat pipe **56**, and then top rim **52**, reflector **53** and main housing **57**.

Another aspect of the present invention is shown in FIGS. **18-20**. Here, the lighting apparatus **500** includes a main housing **501**; a reflector **502** having a front side and a rear side; a top rim **503** coupled to the main housing **501**; a heat conducting body **1000** which is positioned on the front side of the reflector **502** and coupled to the top rim **503**; an LED **504** being positioned facing directly at the front side of the reflector **502** so that light emitted from the LED **504** is substantially or entirely directed to the front side of the reflector **502**.

As shown in FIG. **19**, the heat conducting body **1000** is substantially S-shaped and includes a middle portion **1001** that is bar-shaped or substantially bar-shaped; and curved wing portions **1002** and **1003** which extend from each end of the middle portion **1001**. As shown in FIG. **20**, curved wing portions **1002** and **1002** are coupled to the top rim **503**, wherein the top rim **503** has slots **520** and **521** which permit the curved wing portions **1002** and **1003** to fit within the slots **520**, **521**, respectively; thereby, permitting coupling of the heat conducting body **1000** and the top rim **503**. The heat conducting body **1000** and the top rim **503** can also be coupled via soldering, thermal epoxy or any other techniques known in the art which are used to couple the heat conducting body **1000** to the top rim **503**.

The heat conducting body **1000** includes a mounting platform **530** which is positioned near or at the central optical axis of the reflector **502**, and a mounting plate **531** coupled between the mounting platform **530** and LED **504**. The heat conducting body **1000** also includes a heat pipe is located at the middle portion **1001** and/or one or both of the curved wing portions **1002** and **1003**.

A metal cladding **550** can be coupled to the heat conducting body **1000**. For example, as shown in FIG. **19**, a substantial portion of the middle portion **1001** of the heat conducting body **1000** is coupled to the metal cladding **550**. The metal cladding **550** can be used to secure and direct electrical cable or wires which extends from the top rim **503** to the LED **504** along the middle portion **1001** of the heat conducting body **1000**, and is made of a thermally-conductive material, such as stainless steel, aluminum, copper or any other high-heat conductive material.

As shown in FIG. **18**, the present invention can include a glass cover **800** which is coupled to the top rim **503** and a cap rim **509**. The glass cover **800** protects at least the reflector **502**, the heat conducting body **1000**, the mounting platform **530**, the mounting plate **531** and LED **504** from environmental hazards, such as water and dust. The glass cover can also be used in conjunction with the aspects of the present invention set forth in FIGS. **1-6** and **8-13**.

The present invention can also include a plastic housing **700** that is coupled to the bottom end of the main housing **501**, and a lamp base **701** (e.g., an E26 lamp base, a GU10 lamp base, an E27 lamp base, a G24 lamp base) that is coupled to the plastic housing **700**.

Another aspect of the present invention is shown in FIGS. **21-27**. Specifically, the lighting apparatus **1200** includes a main housing **1300**, a reflector **1800** having a front side and a rear side; a heat conducting head **1500** which is located on the front side of reflector **1800** and is thermally coupled to a heat conducting body **1600**, wherein the heat conducting body **1600** is positioned parallel to a central axis of the apparatus ("central axis **2000**") on the front side of the reflector **1800**, and extends through an opening **1850** of the reflector **1800** and onto the rear side of the reflector **1800**, and is thermally coupled to the main housing **1300**; at least two LEDs **5000**, **5001** are thermally coupled to the heat conducting head **1500** and positioned facing the front side of reflector **1800** at either an inclined angle relative to the central axis **2000** or directly facing the reflector. The LEDs **5000**, **5001** can be position at a range of 0 degree (which is facing vertically downward to the reflector and parallel to the central axis **2000**) to 120 degrees relative to the central axis **2000**.

The lighting apparatus **1200** also includes an anti-glare cap **1700**, which is coupled to the heat conducting head **1500**, and covers at least a portion of the at least two LEDs **5000**, **5001**. As seen in FIGS. **25** and **28**, the anti-glare cap has at least two lips **1700***a*, **1700***b* that cover at least a portion of the at least two LEDs **5000**, **5001**. By doing so, the anti-glare cap helps reduce direct glare caused by directly viewing the at least two LEDs **5000**, **5001**. The anti-glare cap also redirects light emitted from the at least two LEDs **5000**, **5001** to the reflector **1800**.

As shown in FIGS. **21** and **26**, the reflector **1800** has at least two central optical axes, wherein each central optical axis is positioned in a manner which creates a beam angle of at least 30 degrees. The reflector **1800** has at least two independent optical systems (see FIG. **26**) which generate identical and overlapping beams. Such reflector **1800** has 2 to 60 deg beam Full Width Half Maximum ("FWHM").

Heat conducting head **1500** can have a triangular or irregular hexagon side profile, and has at least two mounting areas **1530***a*, **1530***b* which the at least two LEDs **5000**, **5001** may be directly or indirectly coupled thereto, respectively. The heat conducting head **1500** is made of a thermally-conductive material such as aluminum, copper, any other high-heat conductive material, or a combination thereof.

As shown in FIGS. **22**, **24** and **25**, the heat conducting body **1600** comprises at least two heat pipes **1601***a*, **1601***b* thermally coupled to the at least two LEDs **5000**, **5001**, heat conducting head **1500** and main housing **1300**. Main housing **1300** has a slot **1900**, which heat pipes **1601***a*, **1601***b* fit within the slot **1900**; thereby, permitting coupling of the heat pipes **1601***a*, **1601***b* and the main housing **1300**. The heat pipes **1601***a*, **1601***b* can be shaped to optimize heat conduction and transfer efficiency from the at least two LEDs **5000**, **5001** to

the main housing **1300**. For example, as showing in FIG. **24**, the heat pipes **1601***a*, **1601***b* are in a substantially J-shape. The heat pipes **1601***a*, **1601***b* can also be in a substantially L shape, a substantially T shape, or a combination thereof.

In this aspect of the present invention, the heat generated from the at least two LEDs **5000**, **5001** travels the following heat path through the lighting apparatus **1200**: heat conducting head **1500**, heat conducting body **1600**, and then reflector **1800** and main housing **1300**. The reflector **1800** and main housing **1300** act as heat sinks.

Another aspect of the present invention is shown in FIGS. **28-31**. Here, the lighting apparatus **8000** includes lighting apparatus **1200**, wherein one end of the main housing **1300** is coupled with a plastic housing **700**, the plastic housing **700** coupled to a lamp base **701** (e.g., an E26 lamp base, a GU10 lamp base, an E27 lamp base, a GU24 lamp base). The plastic housing **700** contains main circuit boards, and electrically insulate such main circuit boards from the main housing **1300**.

One of the advantages of the present invention shown in FIGS. **21-31** is that it optimizes optical efficiency by decreasing light obscuration caused by a heat conducting body running across the front side of the reflector. In addition, heat conducting body **1600** can handle more heat power than heat conducting body **2**, **51**, **1000** since the heat conducting body **1600** comprises at least two heat pipes **1601***a*, **1601***b* which can direct more heat from the LEDs **5000**, **5001** to the reflector **1800** and main housing **1300**.

Further, a user can mix color from the at least two LEDs **5000**, **5001**, and therefore can choose a wider range of colors of light to emanate from the lighting apparatus **1200**, **1800**.

Heat Conducting Body

As shown in FIGS. **4** and **11**, the heat conducting body **2**, **51** contain a heat pipe **8**, **56** which is cladded by a cladding **9**, **59**, and a mounting platform **5**, **54** located on one side of the heat conducting body **2**, **51** facing opposite the reflector **4**, **53**. The cladding **9**, **59** can be made of a thermally-conductive material such as aluminum, copper, graphite or zinc, and can include a mounting platform **5**, **54**. The cladding **9**, **59** can be used to increase structural strength of the heat pipe **8**, **56**, assist in transferring and spreading the heat from the LED **6**, **55** to the heat pipe, and assist in the transferring and spreading the heat from the heat pipe **8**, **56** to the heat sinks, such as top rim **3**, **52**, reflector **4**, **53** and main housing **57**.

As discussed above, and as shown in FIG. **19**, the heat conducting body **1000** can be coupled to a metal cladding **550**. Metal cladding **550** covers a substantial portion of the middle portion **1001** of the heat conducting body **1000**, and is used for aesthetic purposes, securing electric cable or wires between heat conducting body **1000** and metal cladding **550**, and/or directing such electric cable or wires to the LED **504**. The metal cladding **550** can be made of thermally-conductive material, such as stainless steel, aluminum, copper or any other high-heat conductive material.

Alternatively, as shown in FIG. **14**, the LED **91** can be directly affixed onto a heat conducting body **90** (via the mounting platform **92** of cladding **93**).

In another aspect of the present invention, the heat pipe is not cladded. For example, FIG. **15** shows a heat conducting body **100** wherein an LED **103** is coupled onto a mounting platform **102**, which is, in turn, directly coupled to a heat pipe **101**. The mounting platform **102** can be cylindrically-shaped, and can partially or completely encase at least the center of the heat pipe **101**.

The heat pipe (such as heat pipe **8**, **56**, **101**, **1601***a*, **1601***b*) can be made of porous copper incorporating a large number cavities filled with pure water. As shown in FIG. **7**, water within the heat pipe evaporates to vapor as it absorbs thermal energy from a heat source. See **400** in FIG. **7**. The vaporized water then migrates along the vapor cavity to cooler sections of the heat pipe. See **401** in FIG. **7**. There, the vapor quickly cools and condenses back to fluid, and the fluid is absorbed by the wick, releasing thermal energy. See **402** in FIG. **7**. The fluid then returns along the inner cavities to the heated sections (See **403** in FIG. **7**), and repeats the heat pipe thermal cycle described above. The heat pipe use the above-described mechanism to transmit thermal energy from the LED to heat sinks, such as the top rim **3**, **52**, reflector **4**, **53**, **1800**, and main housing **57**, **501**, **1300**.

The heat pipe can be flattened (in a cross-section direction) into a thin strip in order to minimize light absorption.

Another aspect of the present invention includes a heat conducting body with one or more heat pipes. For multiple heat pipes, each heat pipe is connected to a center hub (like a spoke on a wheel) positioned near or at the central optical axis of a reflector. The center hub acts as a mounting platform for one or more LEDs, and is made of thermally-conductive material such as aluminum, copper or any other high-heat conductive material.

In another aspect of the present invention, the heat conducting body extends up to or near the central axis of a reflector and being coupled to the top rim at only one connection point (such as connection point **900** or **901** for FIG. **1**, or connection point **910** or **911** for FIG. **8**). As a result, the heat conducting body does not form a chord to or a diameter of the top rim of FIGS. **1** and **8**. At or near the central axis of the reflector, the heat conducting body includes a mounting platform with an LED directly coupled thereto, or an LED coupled to a metal core PCB or a mounting plate, which is then coupled to the mounting platform. This alternative aspect of the present invention reduces light blockage caused by the heat conducting body and improves lens efficiency, while promoting heat dissipation and anti-glare.

The mounting platform **5**, **54**, **102**, **530** are made of a thermally-conductive material such as aluminum, copper or any other high-heat conductive material. Also, as mentioned above, the mounting platform provides increased non-glare protection from the LED relative to existing light apparatuses. In the present invention, the possibility of direct glare from the LED is eliminated (or at least mitigated) since (1) the LED is coupled onto the mounting platform and positioned facing directly at the reflector so as that light emitted from the LED is substantially or entirely directed to the reflector, and (2) the mounting platform is shaped (e.g., circular) in a manner which prevents a direct view of the LED at any viewing angle.

Reflector.

The reflector **4**, **53**, **502**, **1800** are made of a thermally-conductive material such as aluminum, and act as a heat sink. Alternatively, the reflector **4**, **53**, **502**, **1800** can be made of a non-thermally-conductive material such as plastic.

As shown in FIGS. **6** and **26**, light emitted from the LEDs **6**, **5000**, **5001** is substantially or entirely directed toward the reflector **4**, **1800**, wherein the reflector **4**, **1800** collimates the light emitted from the LED **6** into a light beam and reflects the light beam with a particular beam angle. The beam angle can range from 2 to 60 Full Width Half Maximum ("FWHM") degree. To eliminate or reduce glare, the reflector **4**, **1800** of the present invention is designed to collect substantially or entirely the light emitted from the LEDs **6**, **5000**, **5001** and redirect the light in a manner which eliminates (or at least mitigates) luminance of the present invention within a direct glare zone (i.e., approximately 45 to 85 degree with respect to vertical).

The reflector **4**, **53**, **502**, **1800** can take a variety of shapes to achieve various light beam patterns. It can be shaped in any conic section (e.g., hyperbola, ellipse or parabola), used singularly or in various combinations, in two-dimension or three-dimensional shapes. Further, the reflector **4**, **53**, **502**, **1800** can be symmetrical or asymmetrical.

LED

An LED can be an LED module with one or more chips. The LED can be a high-powered LED. One or more LEDs can be used in the present invention.

The LED **6**, **55**, **504** are coupled to a metal core PCB **7**, **60** or a mounting plate **531**. In the alternative, the LED **91**, **103** are coupled to the mounting platform **92** and **102**. With respect to the at least two LEDs **5000**, **5001**, such LEDs can be coupled to a PCB (metal core or F4-based) which is then coupled to the heat conducting head **1500**, or can be coupled on the heat mounting head **1500**.

The LED can be soldered onto a metal core PCB, mounting plate, mounting platform, or heat conducting head. Thermal paste, thermal grease, soldering, reflow soldering or any other soldering materials or techniques known in the art can be used to couple the LED onto the metal core PCB, mounting plate, mounting platform, or heat conducting head.

The at least two LEDs **5000**, **5001** can be the same or different colors. Allowing LED **5000**, **5001** to be different colors allows color mixing and variation. LEDs **5000**, **5001** can create a color temperature range of 2700K to 5000K. Such LEDs **5000**, **5001** can be programmed by individually controlling LED current. Power supplies and control unit are needed to allow such color mixing and variation.

Metal Core PCB or Mounting Plate

The present invention includes a metal core PCB (see metal core PCB **7**, **60** shown in FIGS. **3** and **12**). The metal core PCB includes LED circuitry, and acts as a heat-transporting medium. For example, the metal core PCB comprises a base metal plate (copper or aluminum, which is approximately 0.8 to 3 mm thick), a dielectric layer (laminated on top of the base metal plate, which is approximately 0.1 mm thick), and a copper circuit track (printed on top of dielectric layer, which is approximately 0.05 to 0.2 mm thick).

Alternatively, as shown in FIGS. **15** and **16**, a metal core PCB is not included in the present invention in order to further reduce thermal resistance; thereby, reducing LED junction temperature and increasing maximum LED power.

Alternatively, as shown in FIG. **19**, a mounting plate **531** is used, wherein the mounting plate **531** being coupled to the LED **504** and to the mounting platform **530**. The mounting plate is made a thermally-conductive material such as copper or any other high-heat conductive material, and approximately 0.8 to 3 mm thick. Mechanical techniques (such as screws) known in the art are used to couple the mounting plate to the mounting platform, and a thermal grease or paste with high thermal conductivity can be used between the mounting plate and mounting platform.

Top Rim and Cap Rim

The top rim **3**, **52**, **503** are made of a thermally-conductive material, such as aluminum, copper or zinc or any other high-heat conductive material. The top rim **3** acts as a primary heat sink (for example, see FIG. **1**), or, like top rim **52**, **503**, as a secondary heat sink (for example, see FIGS. **8** and **18**).

As shown in FIGS. **16** and **18**, the present invention includes a cap rim **509** which helps secures the glass cover **800** to the top rim **503**.

Main Housing, Plastic Housing and Lamp Base

The main housing **57**, **501**, **1300** are made of a thermally-conductive material, such as aluminum, copper, zinc or any other high-heat conductive material. The main housing **57**, **501**, **1300** act as a primary heat sink (for example, see FIGS. **8**, **17**, **23**). As shown in FIGS. **8**, **17**, **23**, the main housing **57**, **501**, **1300** can have one or more fins **58**, **570**, **1350** and/or take a conical-like or cylindrical-like shape to increase its surface area in order to increase its heat dissipation capacity. The main housing **57**, **501**, **1300** can be substantially frustoconical in shape. The main housing can also be cylindrical or cubical in shape.

In an aspect of the present invention, one end of the main housing **57**, **501**, **1300** are coupled with a plastic housing **700**, the plastic housing **700** coupled to a lamp base **701** (e.g., an E26 lamp base, a GU10 lamp base, an E27 lamp base, a GU24 lamp base). The plastic housing **700** contains main circuit boards, and electrically insulate such main circuit boards from the main housing **57**, **501**.

It will be appreciated by one skilled in the art that the main housing can be utilized in conjunction with the aspect of the present invention set forth in FIGS. **1-6**, and the plastic housing **700** and lamp base **701** can be utilized with the aspects of the present invention shown in FIGS. **1-6**, FIGS. **8-13**, and FIGS. **28-31**.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific embodiments shown and described without departing from the scope of the present invention. This application is intended to cover any adaptations or variations of the specific embodiments discussed herein. Therefore, it is intended that this invention be limited only by the claims and the equivalents thereof.

What is claimed is:

1. A lighting apparatus comprising:

a main housing having a front side and a rear side;

a reflector disposed within the main housing, the reflector having a front side and a rear side, wherein the front side of the main housing opposes, and is spaced apart from the rear side of the reflector;

a heat conducting body comprising at least two heat pipes, wherein a first portion of each of the at least two heat pipes is positioned parallel to a central axis of the lighting apparatus on the front side of the reflector, the at least two heat pipes being at least partially adjoined to one another at the respective first portions of the at least two heat pipes, and at the central axis of the lighting apparatus, and wherein a second portion of each of the at least two heat pipes is positioned at, and spaced apart from the rear side of the reflector and is thermally coupled to the main housing;

a heat conducting head located on the front side of the reflector, the heat conducting head being in contact with, and thermally coupled to the heat conducting body;

at least two light-emitting diodes thermally coupled to the heat conducting head and the heat conducting body, the at least two light-emitting diodes being positioned to face the front side of the reflector so that light emitted from the at least two light-emitting diodes are directed to the front side of the reflector.

2. The lighting apparatus of claim **1**, wherein the at least two heat pipes are substantially J-shaped, L-shaped, or a combination thereof.

3. The lighting apparatus of claim **1**, wherein the heat conducting body provides a pathway for heat to flow from the at least two light-emitting diodes toward the main housing.

4. The lighting apparatus of claim **1**, wherein the reflector has at least two central optical axes.

5. The lighting apparatus of claim 1, wherein one end of the heat conducting body is thermally coupled to the at least two light-emitting diodes, and the other end of the heat conducting body is thermally coupled to the main housing.

6. The lighting apparatus of claim 1, wherein the reflector is in a symmetrical or unsymmetrical shape.

7. The lighting apparatus of claim 1, wherein the main housing is substantially frustoconical, cylindrical or cubical in shape, and is made of a thermally-conductive material.

8. The lighting apparatus of claim 7, further comprising:
a plastic housing, coupled to the main housing; and
a lamp base coupled to the plastic housing.

9. The lighting apparatus of claim 8, wherein the lamp base is an E26 lamp base, a GU10 lamp base, an E27 lamp base, or a GU24 lamp base.

10. The lighting apparatus of claim 1, wherein the main housing comprises one or more heat dissipating fins.

11. The lighting apparatus of claim 1, further comprising the at least two light-emitting diodes being positioned at a range of 0 degree to 120 degrees relative to the central axis of the lighting apparatus.

12. The lighting apparatus of claim 1, wherein the heat conducting head has a triangular side profile or an irregular hexagon side profile, and has at least two mounting areas for the at least two light-emitting diodes, respectively.

13. The lighting apparatus of claim 1, wherein the heat conducting head is made of aluminum, copper, or a combination thereof.

14. The lighting apparatus of claim 1, further comprising a PCB coupled the at least two light-emitting diodes and the heat conducting head.

15. The lighting apparatus of claim 1, wherein the at least two heat pipes are adjoined to one another at the first portion of the at least two heat pipes.

16. The lighting apparatus of claim 1, wherein the front side of the main housing comprises a slot configure to accept the second portion of each of the at least two heat pipes and thermally couple the at least two heat pipes to the main housing.

17. The lighting apparatus comprising:
a main housing having a generally frustoconical shape;
a reflector disposed within the main housing, the reflector having a front side, a rear side and at least two central optical axes;
a heat conducting body comprising at least two substantially J-shaped heat pipes, wherein a first portion of each of the at least two substantially J-shaped heat pipes is bar-shaped and located on the front side of the reflector, and is coupled to a heat conducting head located at or near a central axis of the lighting apparatus, a second portion of each of the at least two substantially J-shaped heat pipes extends through the reflector via an opening at or near the central axis of the lighting apparatus, and a third portion of each of the at least two substantially J-shaped heat pipes is curved and at least a portion of which is coupled to the main housing; and
at least two light-emitting diodes thermally coupled to the heat conducting head and positioned facing the front side of the reflector at an inclined angle relative to a central axis of the lighting apparatus so that light emitted from the at least two light-emitting diodes are directed to the front side of the reflector,
wherein the at least two substantially J-shaped heat pipes are adjoined to one another at the first portion of the at least two substantially J-shaped heat pipes, and at the central axis of the lighting apparatus.

18. The lighting apparatus of claim 1 or 17, further comprising an anti-glare cap coupled to the heat conducting head.

19. The lighting apparatus of claim 17, wherein the main housing comprises a front side and a rear side, the front side of the main housing opposing and being spaced apart from the rear side of the reflector.

20. The lighting apparatus of claim 17, wherein the front side of the main housing comprises a slot configure to accept the third portion of each of the at least two substantially J-shaped heat pipes and thermally couple the at least two substantially J-shaped heat pipes to the main housing.

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